FRED Reports

DEVELOPMENT, DESIGN, OPERATION,
AND PERFORMANCE OF THE KITOI
INCUBATOR FOR SALMON EGG INCUBATION

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July 1985

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ABSTRACT

The Kitoi Incubator was developed and designed in 1976 at the Alaska Department of Fish and Game's Kitoi Hatchery. The incubator incorporates upwelling water flow through a perforated plate and Intalox Saddles and eggs. Tested capacity of the incubator at Kitoi is 700,000 to 800,000 pink salmon, *Oncorhynchus gorbuscha*, eggs to the eyed-egg stage and 420,000 eyed eggs to the fry stage. The average eyed-egg to fry survival during 8 years of testing has been 92% at egg densities of 100,000 to 400,000. Fry from incubators with 400,000 eggs in 1982 and 1983 were the largest produced by the hatchery and heavier than wild fry from the creek. Fry emergence is abrupt and of short duration (50%-80% emergence in 7 days). Fry development at emergence has been normal, ranging between an index of 1.90 and 1.98, with the exception of one year when an index of 1.87 indicated some tissue resorption of fry from a single incubator. Overall, the 8-year performance record of the Kitoi Incubator, based upon egg-to-fry survival, fry size and development, and emergence timing and duration at Kitoi Hatchery, has demonstrated this incubator to be as good or superior to other salmon incubators currently in use.

KEY WORDS: Kitoi Incubator, pink salmon, Kitoi Hatchery, egg incubation, fry emergence.

INTRODUCTION

The increased demand by commercial, sport, and subsistence fishermen for additional salmon in Alaska requires practical and efficient incubators in Alaska hatcheries. Development and testing of prototype incubators in the department's Kitoi Bay Hatchery began in 1972 at Kitoi Bay, Afognak Island. The first incubators were of deep matrix design (Blackett 1974; Bams 1970) with a water manifold system that provided upwelling flow through a layer of birdseye and pea gravel and successive layers of crushed rock and eggs. The incubator simulated natural streambed conditions and satisfied many of the physiological and behavioral requirements of the embryo and alevin (Bams 1969). However, improved egg-to-fry survival and increased size and development of fry were offset by the disadvantage of annually handling and cleaning tons of rock and gravel in a production hatchery. The hatchery space requirements for operation and maintenance of this type of incubator were not practical for salmon production.

By 1974, experiments were being conducted at Kitoi Hatchery and the Auke Creek Hatchery (NMFS) with smaller and shallower-matrix incubators with plastic-turf substrate and perforated plates. In December of 1975, testing of incubators was in progress when Kitoi Hatchery was directed to have an incubation system installed and operable by August 1976 for production of at least 20 million pink salmon, *Oncorhynchus gorbuscha*, fry. Incubator test results were still preliminary at the time, and evaluation had only been completed for one year of operation to the fry stage. Many of the early 1970 design concepts were subject to a state of rapidly changing technology.

The Kitoi Incubator has been tested for 8 years of pink salmon production (Big Kitoi stock) at Kitoi Hatchery. This report describes the incubator, method of operation, and results achieved at Kitoi Hatchery.

KITOI INCUBATOR DESIGN

The original prototype incubator consisted of a 5/8-inch (1.59 cm), exterior-grade plywood box that was 2 feet (0.61 meter) high by 2 feet wide by 3 feet (0.91 m) long (inside dimensions). It also had two, 2- by 2-inch-(5.08 x 5.08 cm) wood rib frames (outer) for bracing. The second generation of this incubator replaces all of the wood with 3/16-inch-(0.48 cm) thick aluminum (5086 or 6061) that is welded to the same dimensions as the wood prototype. Aluminum channel (3-inch [.62 cm] depth by 1.410-inch [3.58 cm] flange width by 0.170-inch [0.43 cm] web thickness) is welded around the upper portion of the sides to add strength and rigidity. The position of the channel is alternated on every other incubator (Figure 1 and Figure 2) so that the incubators will fit tightly side by side.

This concept maximizes use of limited hatchery space for incubators and also provides additional support by adjoining incubators for incubator sides.

Incubator fittings include a 2-inch (5.08 cm), threaded, outlet coupling centered 2½ inches (6.35 cm) from the top; a 1½-inch (3.81 cm), threaded, inlet coupling centered 2 inches (5.08 cm) above the bottom; and a 1½-inch (3.81 cm) threaded coupling for a cleanout plug, 6 inches (15.24 cm) to one side of the inlet and flush with the incubator bottom. All fittings are located on the same end of the incubator. This allows incubators to be placed side by side with all plumbing in line. Two rows of incubators can then be placed back-to-back with all plumbing and valves accessible from the incubator front.

All welds of the incubator are ground smooth to assure removal of rough and sharp edges. This is especially important on the outflow coupling through which the fry pass.

Inside of the incubator, a ½-inch-(1.27 cm) by ½-inch-(1.27 cm) by 1/8-inch-(0.32 cm) thick aluminum angle is welded (continuous

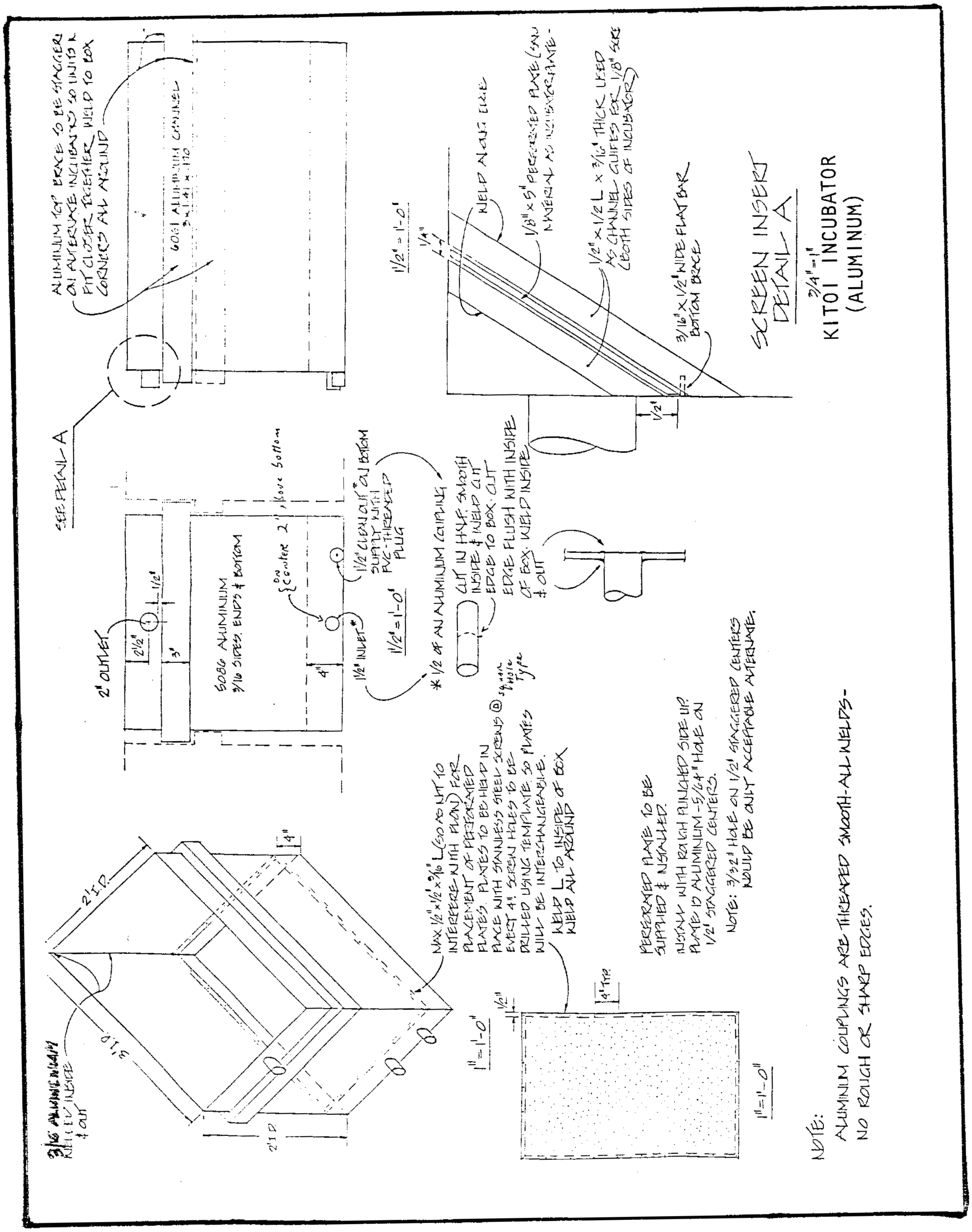

Figure 1. Kitio Incubator drawing. Designed by R.F. Blackett in 1976 for the Alaska Department of Fish and Game, FRED Division, Kitoi Hatchery.

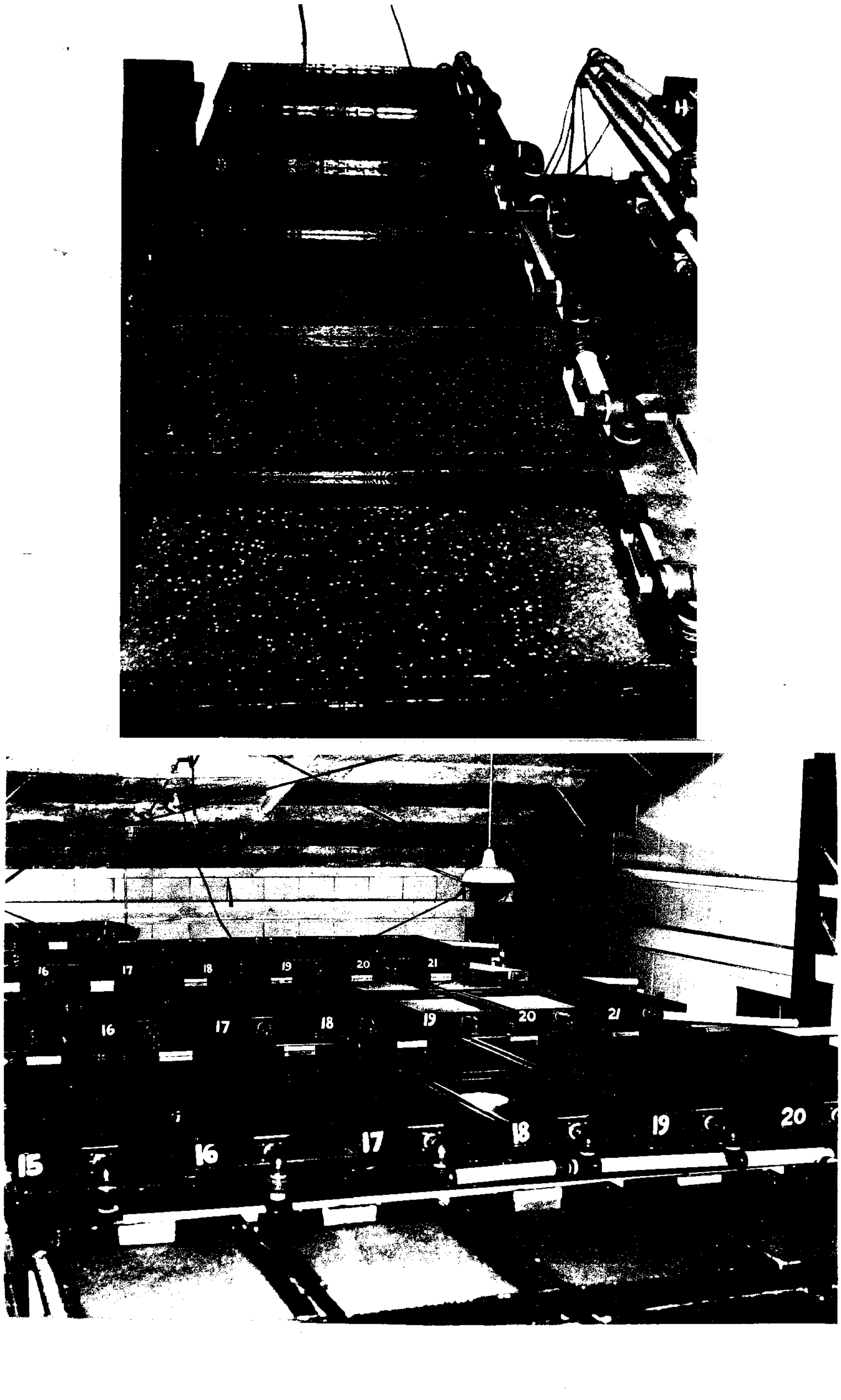

Figure 2. Incubation to the eyed stage (top). Kitoi incubators in Kitoi Hatchery (bottom).

bead) to the sides and ends at a height of 4 inches (10.16 cm) from the incubator bottom. This angle supports a perforated aluminum plate. This bottom plate is 0.125-inch-(0.32 cm) thick aluminum with either 5/64-(0.20 cm) or 3/32-inch (0.24 cm) holes on ½-inch (1.27 cm) staggered centers. The plate is cut to fit flat (rough punched side up) on the angle and flush with the incubator walls. The plate can be held in place with stainless steel screws (hex socket) for the option of removing or replacing the plate or welded in place for permanent installation. If screws are used, holes should be predrilled every four inches (10.16 cm) using a template so the plates can be interchangeable between incubators.

A nontoxic silicone sealant can be used between the plate and incubator walls after the screws are in place, or foam weather-stripping can be placed between the plate and angle. The staggered hole pattern of the plate reduces the likelihood of fatigue cracks from hole to hole that would be more likely to occur in a straight-hole pattern and also provides more plate rigidity.

At the inside top of the incubator, a ½-inch (1.27 cm) by 3/16-inch-(0.48 cm) thick, flat bar is welded ½ inch (1.27 cm) below the bottom of the outlet fitting, the width of the incubator front end. Two ½-inch (1.27 cm) by 3/16-inch (0.48 cm) angles are welded ¼ inch (0.63 cm) apart to each of the inner sides of the incubator as channel guides for screen or perforated plate inserts. The channel guides are at about a 60° angle so that one end of the 5-inch-(12.70 cm) high insert fits flush against the incubator front and flat bar and extends to the incubator top, approximately four inches (10.2 cm) back from the incubator front end. If 1/8-inch (0.32 cm) perforated plate is used as the insert, it should have the same hole diameter and at least twice the open space as the bottom perforated plate.

The insert slides into the channel for the purpose of retaining fry in the incubator. A strip of weatherstripping between the flat bar and the insert bottom maintains a snug fit to keep salmon fry out.

The recommended substrate for the incubator is 1-inch (2.54 cm), black, nontoxic-polypropylene, Intalox Saddles with 1/8-inch (0.32 cm) holes as described by Leon (1975). This product is normally used by the chemical industry for mixing chemicals. The Intalox Saddles have proven to be the best substrate tested for pink salmon incubation at Kitoi Hatchery.

At Kitoi, the incubators are placed side by side in upper and lower tiers (Figure 2) and are supported by 2-inch-(5.08 cm) diameter, galvanized pipe racks. Each incubator has individual plumbing to provide water inflow and outflow. This system could be modified, if necessary, to circulate water between one or more incubators; however, this is not recommended. Maximal incubator efficiency is achieved by a separately controlled water supply. This also reduces the risk of disease and the transmission of pathogens in the hatchery.

All water for each series of incubators is filtered at Kitoi to prevent debris larger than the plate perforations to enter the incubator. Each incubator inlet is valved for flow adjustment. Incubator outlet pipes enter into a common outlet trough that drains into a central fry collection tank. Fry can be either collected from the tank for marking or transport or released through pipes to the creek or rearing pens.

KITOI INCUBATOR OPERATION AT KITOI HATCHERY

At Kitoi Hatchery all water from the hatchery's main line passes through a twin-basket filter, which has replaceable screen inserts, before entering a common pipeline servicing a unit of 14 incubators. Water enters the incubator via the inlet below the perforated plate and upwells through the plate and incubator. The plate assures dispersion of water flow throughout the substrate and eggs. Water then passes through the fry retention plate or screen and the incubator outlet to a common drain and into a fry collection tank.

Chemical treatment of eggs for prevention of *Saprolegnia* is accomplished by introducing the chemical at the filter. A water flow of 10 gallons (37.8 liters) per minute is maintained for normal incubator operation, for egg eyeing, and for incubation of eyed eggs through the fry stage.

For egg eyeing, Vexar netting is placed on top of the perforated plate. While the water is flowing, fertilized eggs are loaded into the incubator until the eggs are within about six inches (15.24 cm) of the incubator top (about three inches [7.62 cm] below the outlet). For pink salmon, each incubator is capable of eyeing 700,000 to 800,000 eggs. At Kitoi, the number of eggs that can be eyed per incubator is based on the capacity of the incubator to hold the eggs and not on biological limitations. Eyed eggs are manually removed from the incubator for sorting dead and live eggs and for egg counting. The Vexar netting contains the eggs in the bottom of the incubator for quick removal.

Eyed eggs are manually layered in substrate for incubation to fry. This procedure involves placing a 3-to-4-inch (8-10 cm) layer of Intalox Saddles (about 40 liters) over the top of the perforated plate, seeding half the eggs on the substrate followed by another layer of substrate, and then placing a final layer of the remaining eggs. A layer of substrate on top of the eggs fills the incubator to within approximately six inches (15.24 cm) of the incubator top. Current egg-loading densities for production at Kitoi are 420,000 pink salmon eggs or 350,000 chum salmon, *Oncorhynchus keta*, eggs per incubator.

Screen or perforated plate inserts at the incubator outlet prevent early emergent fry from flushing out of the incubator. If necessary, the inserts can also be used to retain fry for short periods during normal emergence.

At Kitoi, the incubators are plumbed so that emergent fry can pass out of the 2-inch (5.08 cm) outlet into a common outlet pipe leading to a fry collection trough and holding tank. Fry can be either counted and released via pipes to the bay or rearing pens or held in the tank for some other procedure; e.g., marking and sampling.

Incubator maintenance between fry emergence and egg eyeing requires removal, washing, and disinfection of Intalox Saddles. The incubator is thoroughly washed to remove any residual organic material from the inner sides and the perforated plate. The cleanout plug at the bottom front of the incubator is removed for backflushing the plate and the compartment below the plate. Normally, it is unnecessary to remove the plate to clean this compartment. It can be flushed either from the bottom (through the plug opening) or from the top. At this time, the plate should be inspected to assure that it is still securely fastened with a tight seal around the edges and that the perforations are open.

After disinfection, water flow should be turned on to flush the incubator for at least 24 hours before egg loading. The plumbing, valves, and fittings of each incubator should be checked for proper operation.

KITOI INCUBATOR RESULTS AT KITOI HATCHERY

In 1976, 160 of these plywood Kitoi Incubators were built by Fish and Game technicians and installed in the Kitoi Hatchery (Figure 2). The cost per incubator (plumbed into the system and ready to operate) was $382. This cost included eight hours of labor for fabrication of each unit, substrate, and materials. Additional cost of replumbing the hatchery, construction of fry transport and collection troughs, pipes from the hatchery to the estuary for fry release, incubator support racks, and plumbing for deep-matrix incubators was approximately $34,000. The total cost of upgrading the hatchery with Kitoi Incubators slightly exceeded $95,000.

The first year (1976), 5.8 million pink salmon eggs were incubated in Kitoi and deep-matrix incubators. Incubator substrate at that time was a combination of plastic turf (Astro Turf [FH01] that had been modified by having the backing removed and the holes widened) and a layer of crushed rock that had been placed between the turf and top of the perforated plate. Initial egg-loading density was 100,000 eggs in each incubator.

Testing of Intalox Saddle substrate was begun in 1976. The saddles were compared to turf/rock and rock substrate in replicates of three Kitoi Incubators for each substrate. Testing of substrates and egg densities in Kitoi Incubators was continued until the 1979 brood year when the saddle substrate was used in all Kitoi Incubators. The saddle substrate was superior in producing larger fry that had a shorter emergence period at equivalent or better fry survival than plastic turf. Saddle substrate eliminated the problem of delayed emergence of fry that were unable to get through the layers of turf.

<u>Egg-to-fry Survival</u>

During the testing period (1976-1979), survival from eyed-egg to emergent fry using Kitoi Incubators with saddle substrate averaged 93.4% (90%-98% range) at egg densities of 100,000 to 260,000 (Table 1). In the 1979-1980 incubation period, the hatchery produced 22,145,000 salmon fry (90% survival) in 120 Kitoi Incubators. A single Kitoi Incubator containing 380,000 eyed eggs had 92% fry survival. Egg densities were increased to 400,000 eggs in each of three Kitoi Incubators in 1980. Emergent-fry survival in 1981 averaged 382,000 (96%) per incubator and ranged from 95% to 97%. The following year (1981), 140 Kitoi Incubators contained 401,000 eyed eggs each. Fry survival overall was 83%, the lowest recorded for this

Table 1. Performance of Kitoi Incubators with Intalox Saddles in production of pink salmon fry at Kitoi Bay.[a/]

Incubation year	No. incubators	Eyed eggs/ incubator	Emergent Salmon Fry Total no.	%	Mean no.	Survival range %
1976-77	3	100,000	274,000	91	91,000	90 - 94
1977-78	3	150,000	417,000	93	139,000	92 - 94
1978-79	3	200,000	566,000	94	189,000	94 - 94
	3	230,000	656,000	95	219,000	93 - 98
	3	260,000	732,000	94	244,000	93 - 94
1979-80	120 b/	205,000	22,145,000	90	185,000	86 - 100
	1	380,000	349,000	92	-	- -
1980-81	104 b/	262,000	25,181,000	92	233,000	86 - 97
	3	400,000	1,147,000	96	382,000	95 - 97
1981-82	140 c/	401,000	46,659,000	83	333,000	- -
1982-83	1	400,000	367,000	92	-	- -
	139 K d/ 40 NT 9 DM	400,000 300,000 1,135,000	71,758,000	92	-	- -
1983-84	140 K 50 NT 14 DM	420,000 300,000 1,479,000	87,270,000	92	-	- -
1984-85	135 K 55 NT 6 DM	420,000 298,000 800,000	e/			

a/ Egg and fry numbers rounded to nearest 1,000. Fry were counted by hand for test incubators.
b/ In 1979-80 and 1980-81, fry production is based upon hand counts from ten index incubators.
c/ After 1981, all fry counts by Northwest Marine Technology, Inc. electronic fry counters.
d/ Beginning with the 1983 fry emergence, counts are for all hatchery incubators combined. Incubator types: Kitoi Incubator (K), NOPAD Trays (NT), Deep Matrix (DM).
e/ Incubation of eggs still in progress at the time of writing this report.

incubator in 8 years of use at Kitoi Hatchery. Fry counts, with the exception of a single Kitoi Incubator, were combined for all incubators (including Nopad and deep-matrix types) in the hatchery after 1982. However, 71%, 62%, and 73% of the eyed eggs in 1982, 1983, and 1984 respectively were placed in Kitoi Incubators. In 1983 and 1984, Kitoi Incubators were loaded at a density of 420,000 eggs each. The egg-to-fry survival for all incubators combined was 92% in 1983 and 1984.

Overall, based upon 8 years of testing and production use of the Kitoi Incubator for pink salmon at Kitoi Hatchery (Table 1), this incubator can usually be expected to produce eyed-egg-to-emergent-fry survivals of between 90% and 95%, assuming water quality and other incubation conditions are similar to the Kitoi Hatchery. The average overall survival at Kitoi Hatchery has been 92% at incubator egg densities of 100,000 to 400,000. The maximal egg density for the Kitoi Incubator (at a fry survival limit of >90%) has not been determined, but it does exceed 400,000 pink salmon eggs and probably exceeds (though not tested) the 420,000 egg density per incubator used at Kitoi in 1983 and 1984. The incubator lacks space for increasing the egg numbers beyond this level.

Fry Size and Development

The size (length and weight) of emergent salmon fry at a given stage of development has been generally accepted as the criterion for evaluating and comparing various incubator types and hatchery methods (Bams 1970, 1972, 1974, 1984; Blackett 1974; Bailey et al. 1977). Methods of fry collection and measurement of length and weight of preserved fry at Kitoi are described by McDaniel and Collins (1984) and were basically adapted from Bams (1970). Fry development is expressed as an index of the ratio of wet weight to length, termed K_D by Bams (1970) whereby:

$$K_D = \frac{10 \sqrt[3]{\text{weight in mg}}}{\text{length in mm}}$$

The mean length, weight, and development index of pink salmon fry from Kitoi Incubators (saddle substrate) at egg densities ranging from 200,000 to 400,000 eggs is given in Table 2. In 1978, 1979, and 1981, wild fry from Big Kitoi Creek were collected to compare their size and development with incubator fry. In all years (1978-1983), with the exception of one incubator at the 380,000-egg density in 1980, weight of incubator fry exceeded weight of creek fry at emergence. In 1982 and 1983, fry from Kitoi Incubators (400,000-egg density) were substantially heavier than in previous years (Table 2 and Figure 3). With the exception of fry from the 400,000-egg incubators in 1981 that were 0.84 mm less, the length of incubator fry has been slightly less (<0.25 mm) than creek fry. Length of incubator fry in 1982 and 1983, however, was greater than any previous year. Fry from the 400,000-egg incubators in 1982 and 1983 were the largest produced by the hatchery and heavier than any wild fry sampled from the creek. Development index for incubator fry was within the normal range expected at the emergence stage (1.90 to 2.00) and equivalent to wild fry with the exception of the 380,000 egg-incubator in 1980. An index of 1.87 and the light weight of these fry indicate complete utilization of yolk and the beginning of resorption of body tissue prior to emergence. Normally this condition would be associated with delayed emergence, but this was not apparent for this incubator. An undetected water supply failure is another possibility, though this is also unlikely because the egg-to-fry survival was 92%.

Fry Emergence

Similar to that reported by Leon (1980), fry emergence from Kitoi Incubators with saddle substrate tends to be abrupt and of shorter duration than with turf or gravel substrates. It is a normal occurrence at Kitoi for 50%-80% of the pink salmon fry to emerge in a 7-day peak period at the 400,000 egg-density level

Table 2. Mean length, weight, and development index (K_D) of pink salmon fry from Big Kitoi Creek and Kitoi Incubators (saddle substrate) at various egg densities.[a/]

Source or incubator egg density	Sample size	Length (mm) mean	Length (mm) S.D.	Weight (mg) mean	Weight (mg) S.D.	K_D mean	K_D S.D.
			1978				
Creek (Wild)	150	32.90	0.99	256.13	23.05	1.93	0.04
200,000	450	32.61	1.09	257.39	23.15	1.95	0.05
			1979				
Creek (Wild)	145	33.37	1.54	263.21	31.71	1.92	0.08
200,000	447	33.13	1.34	270.93	33.98	1.95	0.06
230,000	450	33.17	1.14	264.37	29.25	1.93	0.04
260,000	449	33.23	1.23	268.47	29.44	1.94	0.04
			1980				
200,000	150	32.65	1.14	246.95	28.59	1.92	0.04
380,000	149	32.68	1.22	229.68	26.37	1.87	0.04
			1981				
Creek (Wild)	150	33.06	1.06	250.37	26.53	1.90	0.05
260,000	450	32.98	1.19	262.27	32.65	1.94	-
400,000	450	32.22	1.70	262.39	31.21	1.98	-
			1982				
400,000	100	33.78	1.06	287.55	25.50	1.95	0.04
			1983				
400,000	150	33.31	1.41	286.39	37.14	1.97	0.05

a/ Fry samples taken from one or more incubators at approximately 25%, 50%, and 75% emergence in 1978, 1979, 1980, 1981, and 1983. In 1982 samples were taken at 25% and 50% emergence. Creek fry were sampled at approximately equivalent emergence rates.

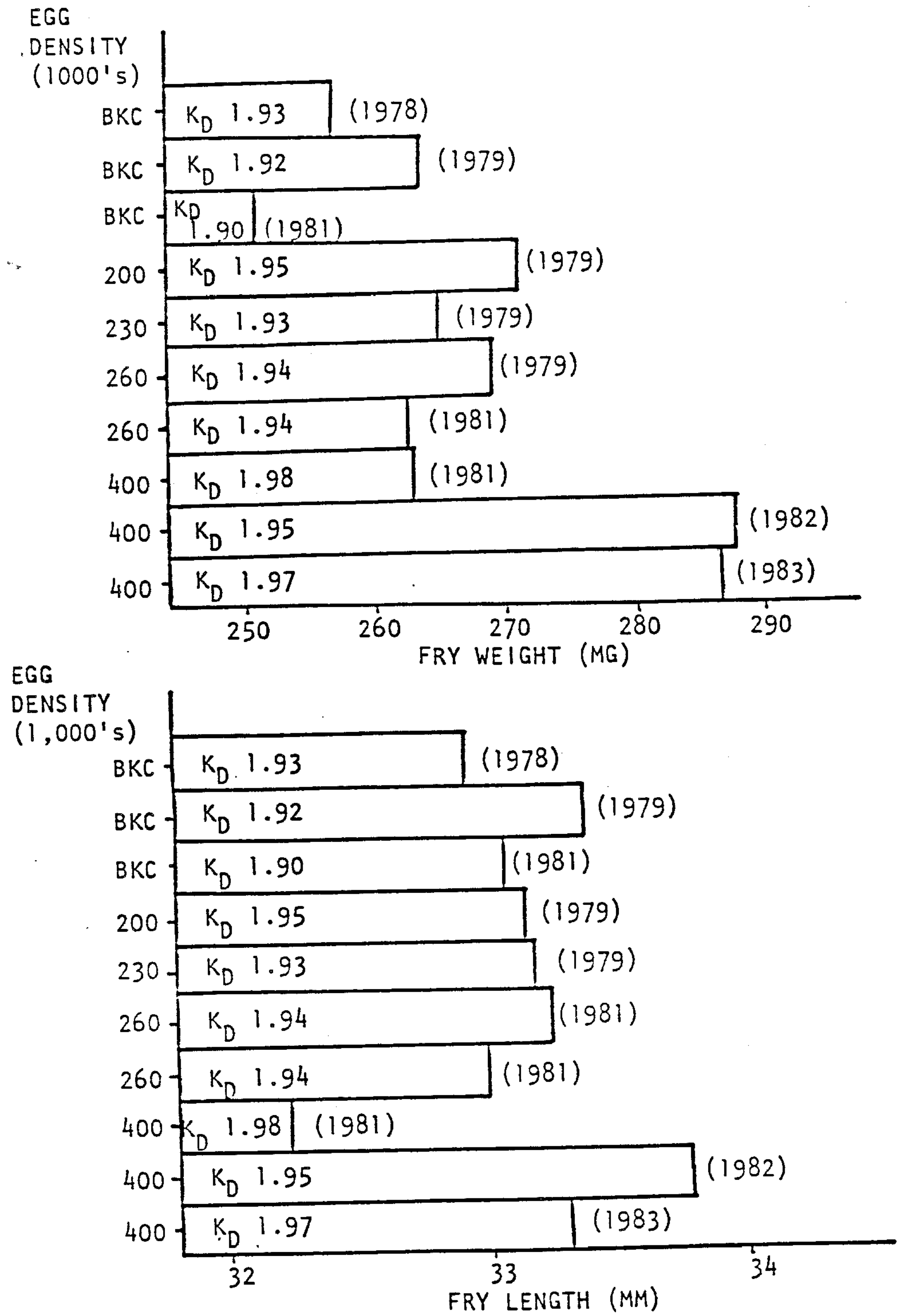

Figure 3. Comparison of mean length and weight of emergent pink salmon fry from Kitoi Incubators at various egg densities and Big Kitoi Creek (BKC) wild fry.

(Figure 4 and Figure 5). The emergence period depends in part on duration of the egg take and rate of development to the fry stage. Typically at Kitoi, pink salmon fry begin emergence by early April and complete emergence by early May. Emergence timing of fry at various egg densities of less than 400,000 is shown in Appendix Figures 1 and 2 (taken from McDaniel and Collins 1984; Probasco 1982). Doubling egg density from 200,000 to 400,000 eggs has not changed emergence timing of fry from Kitoi Incubators.

Water temperature influences rate of embryonic development and, in turn, fry emergence. At Kitoi, initiation of peak emergence from Kitoi Incubators usually occurs at between 800 and 1,000 Temperature Units (TUs).

Water Quality at Kitoi Hatchery

All testing of Kitoi Incubators has been accomplished at the Kitoi Hatchery. The results achieved at Kitoi may not apply to hatcheries with water of lower quality or of a different temperature regime, because water quality affects egg and fry incubation and incubator performance.

The range of some water quality parameters measured at Kitoi during the test period is given in Table 3 to enable comparison with other hatchery water. Water at Kitoi is of excellent quality. It is usually near neutral pH and tends to be close to the point of dissolved oxygen saturation for most of the incubation period.

For incubation of pink salmon, water is taken from the surface of Big Kitoi Lake, a virgin watershed 30.5 m above sea level. An epoxy-lined steel pipe, 35.6 cm in diameter and approximately 0.5 km in length, transports water to the hatchery by gravity flow from a dam at the lake outlet. The water supply is dependable and has sufficient head and pressure for continuous operation of the incubators.

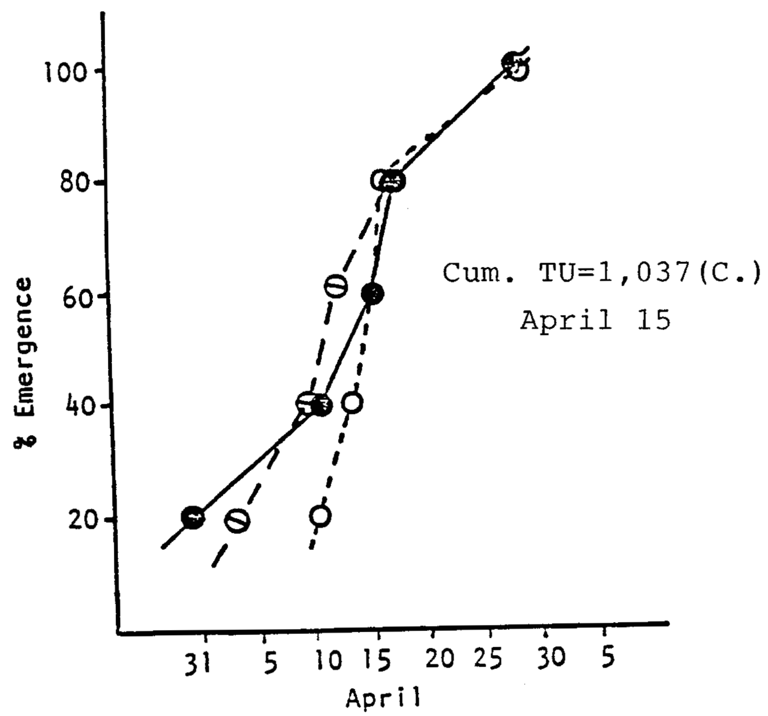

Figure 4. Pink salmon fry emergence in 1981 from three Kitoi Incubators at 400,000-egg density of a single egg lot.

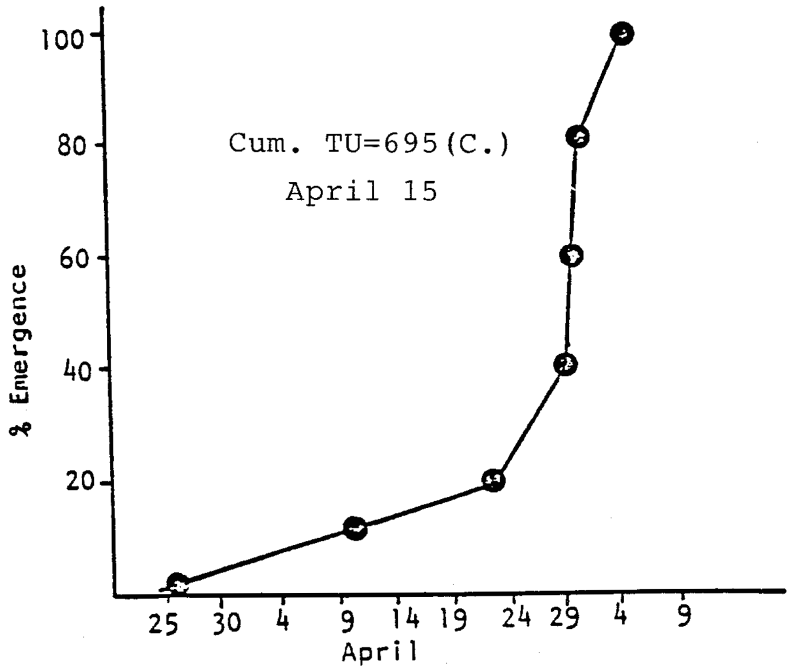

Figure 5. Pink salmon fry emergence in 1983 from a Kitoi Incubator at 400,000-egg density of a single egg lot (late egg take).

Table 3. Range of water quality at Kitoi Hatchery during egg incubation, 1976 - 1984[a]

Year	Test period	Water temp °C.	Dissolved[b] oxygen(ppm)	pH	Free CO_2 (ppm)	Ammonia NH_3(ppm)
1976-77	11/3-4/06	2.1-4.6	12-14	7.5	1.0-3.0	0.10-0.35
1977-78	11/3-4/06	0.5-4.9	12-14	7.5	1.5-2.5	0.00-0.30
1978-79	11/1-5/05	1.6-5.8	12-14	6.0-7.5	1.5-3.0	0.00-0.55
1979-80	11/1-4/29	1.2-6.5	-	-	-	-
1980-81	10/29-03/25	1.9-6.1	11-14	5.9-8.5	1.0-2.5	0.05-0.45
1981-82	11/10-03/25	1.6-4.5	12-14	6.5-7.5	1.0-1.2	0.10-0.80
1982-83	12/30-03/17	1.3-2.6	11-14	6.8	1.0-2.5	-
1983-84	11/1-5/01	1.3-4.9	9-12	7.0	1.5	-

a/ Water temperature recorded daily; water chemistry recorded once a week. The ranges include incubator effluent water from all incubator types. Temperatures recorded by either hand-held thermometer or Yellow Springs Instrument Company (YSI) meter and probe. Water chemistry recorded by YSI oxygen meter and Hach water analysis kit and procedures.

b/ Rounded to nearest ppm.

DISCUSSION

This report describes the development, design, operation, and performance of the Kitoi Incubator at Kitoi Hatchery. Until recently, Kitoi Hatchery and a private nonprofit hatchery at Valdez were the only hatcheries to use Kitoi Incubators. In 1984 several new aluminum Kitoi Incubators were installed at Kitoi and at three other State hatcheries for trial use. The cost per incubator (as shown in the plans) was $408. Fabrication of 100 or more Kitoi Incubators on a single order would decrease the cost to approximately $350 each (1984 price quote).

With the concept in mind that complexity increases probability of failure, the Kitoi Incubator was designed to be as simple as possible. Some incubator designs in the past have suffered because the human perspective of fish requirements was somewhat different than actual fish requirements. Entrapment of air, which has not been a problem with the Kitoi Incubator, continues to be a major problem, causing egg and fry mortality with more complex incubators. Additionally, the Kitoi Incubator was purposely designed as a small, modular unit. Another consideration was construction of an incubator that would be practical and simple for fish culturists to operate and maintain.

Incubator performance is judged on the basis of egg-to-fry survival, fry size and development at emergence, and emergence timing and duration. Results must be consistent and repeatable year after year for dependable incubation of salmon in the hatchery. The 8-year performance record of the Kitoi Incubator at Kitoi Hatchery demonstrates that this incubator is as good as or superior to any other salmon incubator currently in use.

In judging the value of fry size, it is assumed that larger, heavier fry have a greater probability of survival to adult fish than smaller fry when released directly into the estuary. Bams (1972, 1974) has demonstrated that fry from gravel substrate incubators were of sufficient quality to survive to adults at either the same or not less than 90% of creek fry survival. At Kitoi there have been 2 out of 4 years when marked fry from Kitoi Incubators (saddle substrate) were recovered as adults at an equivalent (96%) or higher rate than marked creek fry from Big Kitoi Creek, which is adjacent to the hatchery.

The year-to-year variability in Kitoi pink salmon fry size from hatchery incubators and the substantially increased size found in 1982 and 1983 is surprising. This variability might be expected for creek fry, but in hatchery incubators, the environmental conditions influencing fry size at emergence are more controlled. Fry size did not decrease with increases in egg densities in Kitoi Incubators. The increase in fry size in recent years at the 400,000-egg density may actually be more a result of natural variability rather than incubator egg density. This natural variation in size could mask differences in size that might have resulted from the various egg densities tested.

Emergent salmon fry are at a critical stage in their life, because at this time the yolk sac is normally close to complete aborption and feeding has not begun. During the period of emergence the fry are essentially at a point when endogenous nutrients are near exhaustion. Therefore, the stage of fry development, emergence timing, and emergence duration is extremely important in the hatchery. The condition of fry at this time could affect growth and survival at later life stages.

Development of fry at emergence is expressed as an index (K_D). An index value of 2.00 or greater indicates early or premature emergence of pink salmon fry with the yolk sac not yet absorbed. An index of 1.90 or less indicates complete absorption of yolk and the initial stage of body tissue resorption to maintain life. Fry emergence should occur within the range of index values between these extremes. At emergence, fry should have nearly completed yolk absorption, the ventral slit should be nearly closed or completely closed, and resorption of body tissue should not occur. A salmon incubation system must consistently have emergent fry within this range of development or incubator performance will be unsatisfactory.

There has been only 1 year (1980) when a single Kitoi Incubator (380,000-egg density) may have produced inferior fry in the stage of tissue resorption (assuming the fry samples were representative). I have no explanation for the marginal performance of this incubator as indicated by the mean fry weight (229.68 mg) and development index (1.87).

The short duration of pink salmon fry emergence from Kitoi Incubators with saddle substrate is advantageous for reasons of fish health and hatchery logistics. The volitional release of fry from Kitoi Incubators, which usually occurs throughout April at Kitoi Hatchery, is also an advantage, because emergence is usually at a time when food is available at water temperatures that stimulate vigorous feeding.

Saltwater rearing of salmon fry can more than double marine survival. Speculation that saltwater rearing can compensate for small or poor quality fry from an incubator is perhaps true to some extent, but the increased growth and survival that can be attained from large, unstressed, and good quality fry going into the rearing pens to begin with should also be considered.

Incubators are the "heart" of the hatchery. To compensate for poor incubator performance or other operational problems is impractical and unnecessary. Incubators such as the Kitoi Incubator, which has a proven record of satisfactory results and dependability, are essential for efficient hatchery operation. Evaluation of incubator performance is necessary to assure that fish health and survival are not being compromised. Kitoi Incubators are currently in use for chum salmon at Kitoi Hatchery, but data are insufficient for inclusion in this report.

ACKNOWLEDGMENTS

The assistance of numerous Fish and Game Department biologists, technicians, and fish culturists who collected data on the Kitoi Incubator over the years is duly acknowledged. Special thanks are due to Tim Joyce, Kitoi Hatchery Manager, who provided much of the recent information on performance of the Kitoi Incubator and whose suggestion of obtaining a patent for the incubator resulted in this report as part of that process.

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APPENDIX

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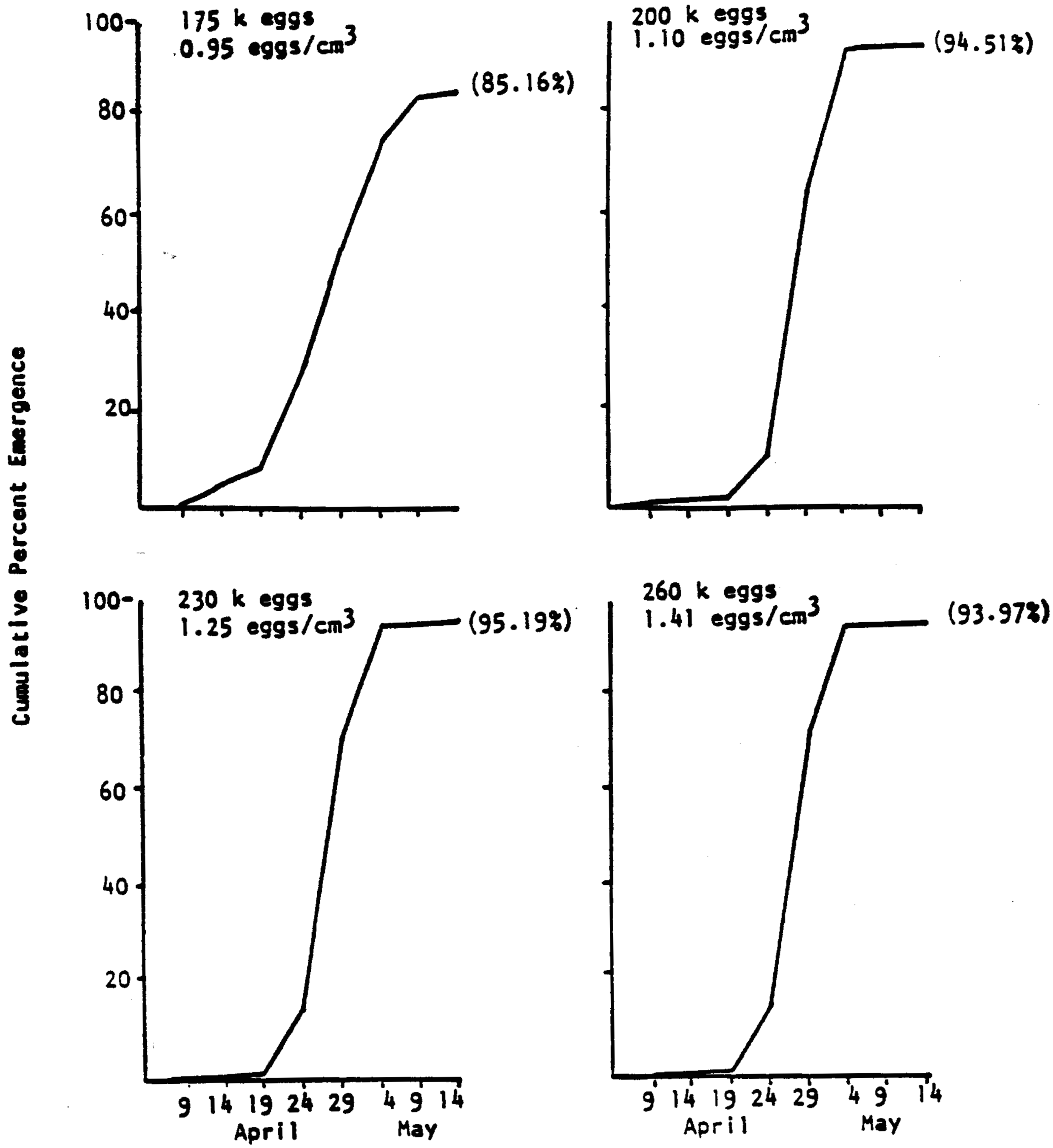
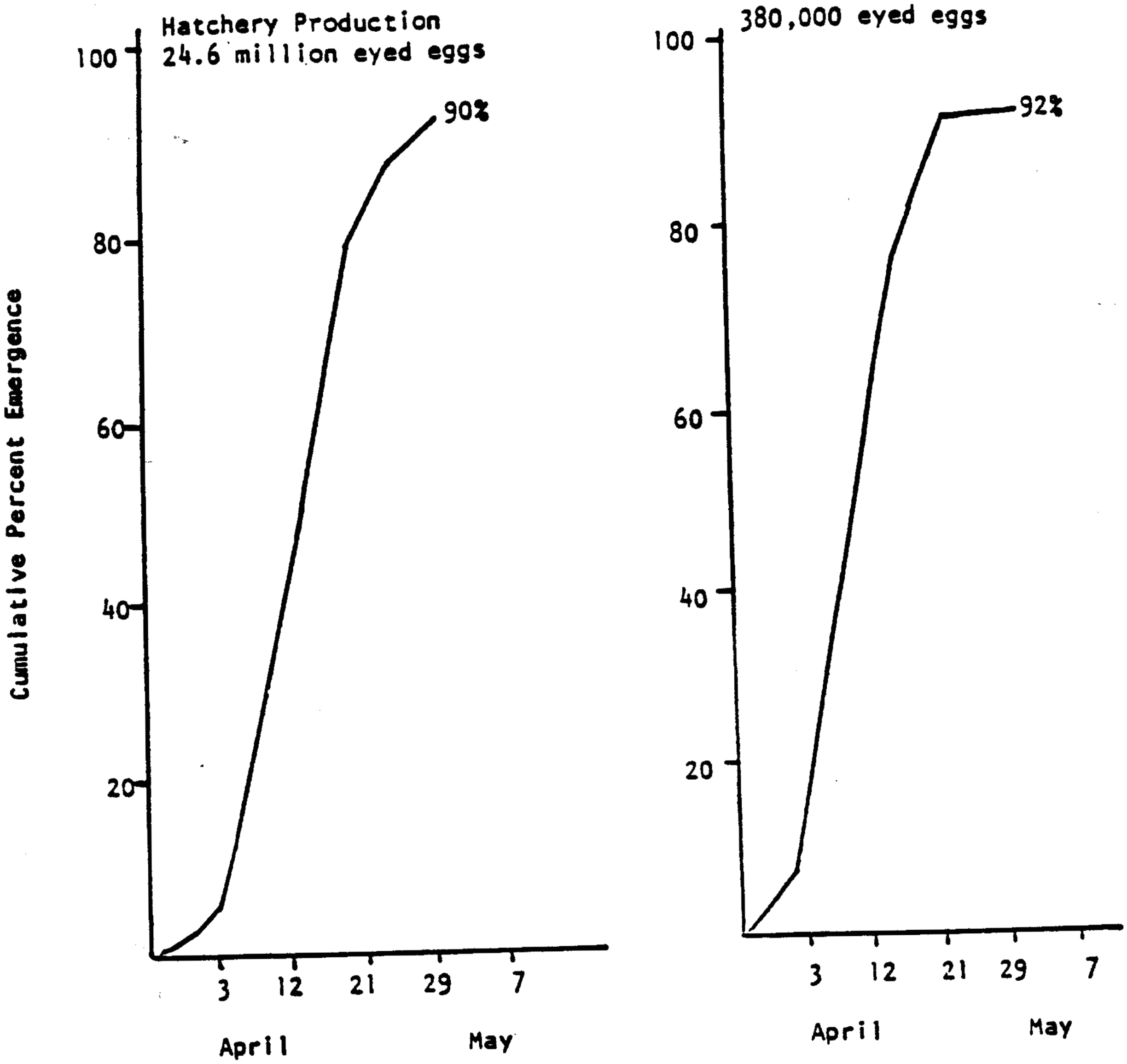


Appendix Figure 1. Pink salmon fry emergence timing at four egg-incubation densities, May 1979. Eyed-egg-to-emergent fry survival is in parenthesis. Taken from McDaniel and Collins (1984).



Appendix Figure 2. Pink salmon fry emergence timing and eyed-egg-to-fry survival for hatchery production (120 Kitoi Incubators) and a single Kitoi Incubator with 380,000 eggs, 1980. Taken from Probasco (1982).