

FRED Reports

EFFECT OF PINK SALMON INCUBATION
AND REARING TECHNIQUES ON HATCHERY
AND MARINE SURVIVAL FOR THE 1978
KITOI BAY HATCHERY BROOD

by
Tim R. McDaniel
and
Jean Collins
Number 40



Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
Enhancement and Development

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ABSTRACT

Hatchery techniques involving the incubation and rearing of pink salmon (Oncorhynchus gorbuscha) fry were tested to evaluate methods of increasing the marine survival of hatchery-produced fry. Kitoi incubation units (vertical upwelling incubators with a substrate volume of 184,500 cm³) were seeded with eyed-egg densities of 1.10 eggs/cm³ (200,000 eggs/unit), 1.25 eggs/cm³ (230,000 eggs/unit), and 1.41 eggs/cm³ (260,000 eggs/unit). Eyed-egg to emergent fry survival and fry development for each test unit were compared to control units seeded at a density of 0.95 eggs/cm³ (175,000 eggs/unit). Mean eyed-egg to fry survival ranged from 94% to 95.2% for the test units and 85.16% for the control units. Emergent fry development, as measured by the ratio of weight to length, was similar for all sources.

Six groups of marked fry were released to compare ocean survival of (1) short-term reared fry versus fry released volitionally and unfed, (2) emergent fry from the 1.41 eggs/cm³ density incubation versus emergent fry from the control, and (3) wild fry from Big Kitoi Creek versus fry released volitionally and unfed. Commercial catches and hatchery brood stock were sampled to recover marked adults. Marine survival was estimated at 2.81% for the reared group versus 1.62% for the unfed release group. Fry from the density test were estimated to have survived to adult at a higher rate (2.61%) than fry from the corresponding control group (1.62%). Estimated ocean survival of wild fry from Big Kitoi Creek was higher (2.71%) than all groups of unfed, volitionally released hatchery fry.

Contributions of hatchery-produced pink salmon to commercial catches were estimated from mark recovery data. An estimated 360,000 hatchery-produced pink salmon were taken in commercial

catches in the Kitoi Bay area. Hatchery production accounted for approximately 52% of the commercial catches in the east Afognak district.

Keywords: Oncorhynchus gorbuscha, pink salmon, incubation techniques, short-term rearing, marine survival.

INTRODUCTION

Methods of increasing Pacific salmon (Oncorhynchus spp.) survival and production are currently being tested at hatchery facilities throughout the state of Alaska. Kitoi Bay Hatchery is a pink salmon (Oncorhynchus gorbuscha) production facility on Afognak Island near Kodiak (Figure 1). Experimentation there has addressed two major goals. The first goal was to define the optimal loading density (eggs per unit volume) of Kitoi incubation units. The criteria were to maintain a high level of eyed-egg to fry survival and to produce fry comparable to those produced naturally. The second goal was to determine the effects of short-term saltwater rearing and release timing on the ocean survival of hatchery-produced pink salmon.

This report presents the results of studies involving the release of 1978 brood pink salmon fry from the Kitoi Bay Hatchery and the subsequent adult return.

Project Background

The incubation studies at the Kitoi Bay Hatchery are a continuation of pilot projects designed to evaluate the feasibility of crushed rock incubation systems for salmon enhancement in Alaska (Blackett 1974; Bailey 1972, 1973). Development of incubation technology has led to the widespread

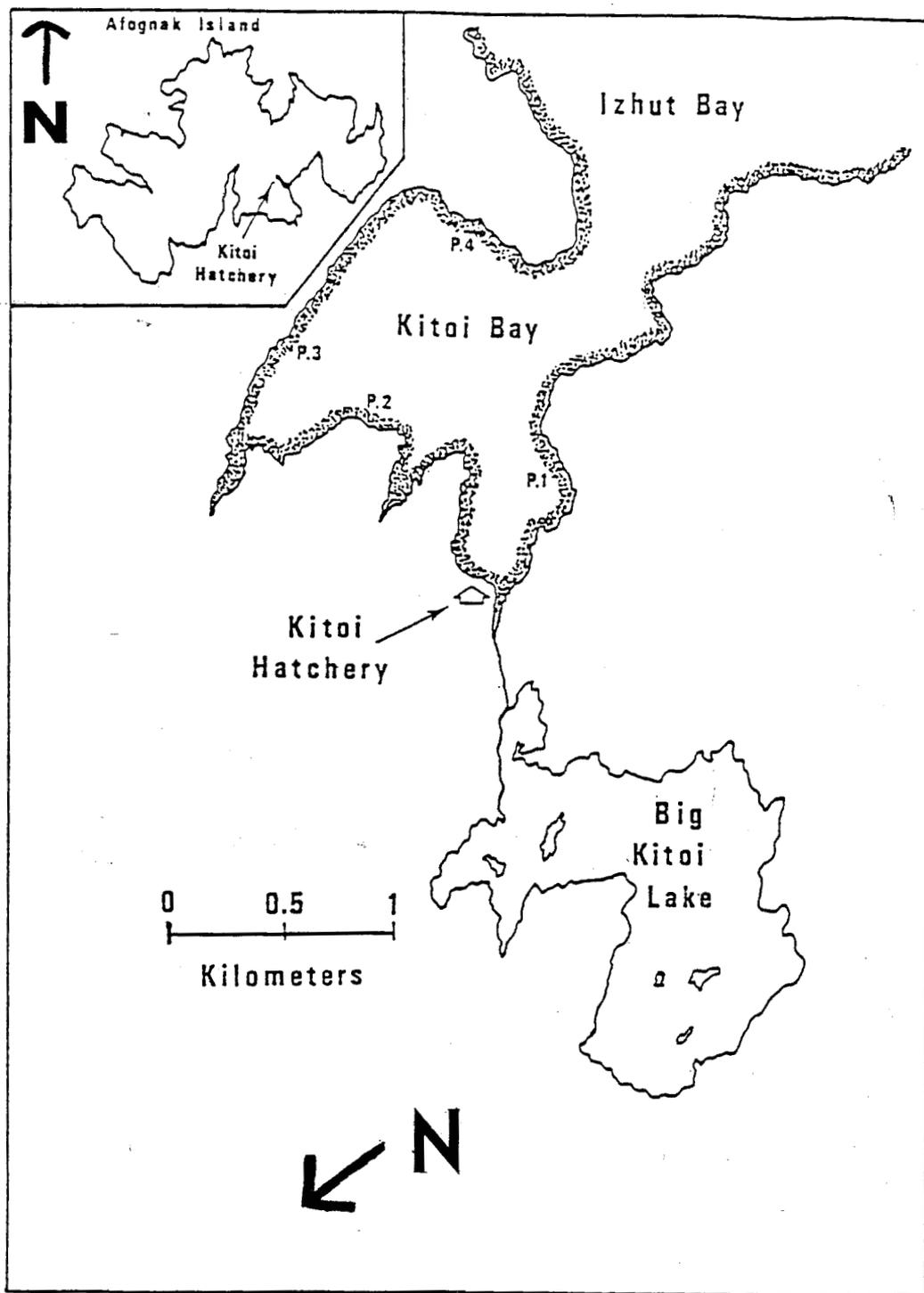


Figure 1. Location of Big Kitoi Creek and the Kitoi Bay Hatchery on Afognak Island. Plankton sampling stations in Kitoi Bay are listed as P.1 through P.4.

use of a light, plastic, artificial substrate (Intalox saddles) in production hatcheries as described by Leon (1975). The use of this substrate eliminates the problems associated with moving large quantities of crushed rock for production incubation systems and supplies a more uniform matrix with greater alevin-loading capacity.

During incubation testing, Intalox saddles were used as a substrate in the incubation units. These units were loaded at various egg densities and were evaluated in terms of the relative difference in eyed-egg to fry survival, emergent fry quality, and fry to adult survival.

Studies dealing with pen culture of emergent pink salmon fry indicate that ocean survival can be increased by short-term saltwater rearing (Martin et al. 1981; Dudiak and Quimby 1979).

Heard (1978) states that survival of pink salmon should theoretically be improved if fry were raised to a larger size in a protected estuarine environment and released in a manner that does not disrupt the migration timing and internal clock during their ocean life. Short-term rearing may mitigate early estuarine mortality of migrant pink salmon fry and allow a delayed release of fry into marine nursery areas when natural feeding conditions are near optimal levels. Preliminary results of rearing studies at the Kitoi Bay Hatchery indicate an increase in ocean survival of reared pink salmon fry compared to unfed, volitionally released hatchery fry (McDaniel 1980).

Study Site

Big Kitoi Creek, adjacent to Kitoi Hatchery at Kitoi Bay, Afognak Island (Figure 1), has a native stock of pink salmon that spawns in the intertidal area to 120 m upstream. A falls

prevents fish passage further upstream. A spawning area of approximately 2,500 m² has produced estimated adult returns of up to 35,000 fish; however, annual returns usually range from 4,000 to 8,000 pink salmon (Blackett 1974).

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 (Blackett 1974).

Hatchery incubation of pink salmon began in 1972 with a limited number of pink salmon eggs taken on a yearly basis for experimental purposes. In 1976 the hatchery incubation system was rebuilt with 160 "Kitoi" incubation units for pink salmon production. Adult salmon returns produced by the hatchery have resulted in increased commercial fishing activity and pink salmon catches in outer Izhut Bay. Special fishery openings inside Kitoi Bay have also been necessary to harvest the pink salmon in excess of hatchery brood stock and escapement requirements.

METHODS AND MATERIALS

Incubation Studies

Egg Sources and Treatment:

Pink salmon eggs were obtained from hatchery brood stock in 13 separate lots between 1 September and 19 September. Eggs were removed from females by incision and placed in plastic spawning buckets. The milt from one male was added to the eggs from three females. This procedure was repeated until the eggs from 15 females and the milt from five males were

added to each bucket. The eggs were transported to the hatchery building, and a small amount of water was added to aid fertilization. The eggs were then washed and placed in incubation units to continue development. Standard hatchery procedures involving malachite green treatments, shocking, and picking (Anon. 1980) were followed.

Incubator Design:

Kitoi incubation units were of a vertical, upwelling design consisting of fiberglass-reinforced plywood boxes measuring 61-cm width by 91-cm length and by 61-cm depth (inside dimensions), with a perforated water dispersion plate suspended 7.6 cm above the bottom. The dispersion plate consisted of a 61-x 91-cm sheet of polypropylene that was perforated with a staggered pattern of 0.23-cm diameter holes that were 1.3-cm on center. The plate was attached and sealed to a 1.3-cm² cribbing strip, which circumvented the inside of the incubator.

Water entered each incubation unit below the perforated plate through a 5-cm (inside diameter) PVC pipe at 37 to 38 liters per minute. Water entering the incubators was filtered through twin basket filters with 0.6-mm mesh screen inserts to remove organic debris. Water to all incubation units was unheated and not recirculated. Water and emergent fry exited the incubator through a 5-cm (inside diameter) PVC drain pipe located approximately 10 cm below the top edge.

Egg Incubation:

The number of live eggs remaining after shocking and picking and those put into each incubation unit were determined gravimetrically. Three subsamples were counted to determine the number of eggs per unit of weight. Eggs were placed in

incubators and "seeded" into the substrate by backflushing the incubator while the eggs and substrate were washed down with a hose. Water flows were then readjusted to 37 to 38 liters per minute.

A test rack of incubators was installed to make access and fry counting easier. Three egg-loading densities were tested with three replicate incubators for each test (Table 1). Three additional incubation units were randomly selected from the production system as controls.

Water flows and water chemistry were checked weekly, while water temperature in the incubation units and Big Kitoi Creek were recorded daily.

Fry Emergence and Enumeration:

Prior to fry emergence, collection troughs were positioned at the outlets of all test and control incubators. Emergent fry were retained in individual nets and enumerated on a daily basis. Emergent fry were either hand counted or enumerated by multiplying a known mean number of fry per unit weight by the total weight of emergent fry from each unit. After counting, fry were either placed in the production collection system, retained for marking, or analyzed for fry quality.

An index net was placed in Big Kitoi Creek to capture wild fry. Captured fry were enumerated daily and either released back into the creek, retained for marking, or analyzed for quality.

Fry Quality Samples:

Samples of 50 fish each were collected from test and control incubators at approximately 25%, 50% and 75% of emergence. Three samples of 50 fish each were taken from creek fry that

Table 1. Pink salmon incubation schematic illustrating egg lots and loading dates of various density tests conducted at the Kitoi Bay Hatchery, 1978 - 1979.

Control - 175,000 eggs/unit (0.95 eggs/cm³)

Inc. 4-9	Inc. 4-15	Inc. 5-2
Lots 12, 13	Lot 7	Lot 7
Loaded 10/19/79	Loaded 10/10/79	Loaded 10/11/79

Density I - 200,000 eggs/unit (1.10 eggs/cm³)

Inc. 6-1	Inc. 6-3	Inc. 6-7
Lot 8	Lot 8	Lot 8
Loaded 10/11/79	Loaded 10/11/79	Loaded 10/11/79

Density II - 230,000 eggs/unit (1.25 eggs/cm³)

Inc. 6-2	Inc. 6-6	Inc. 6-9
Lot 8	Lot 8	Lot 8
Loaded 10/11/79	Loaded 10/11/79	Loaded 10/13/79

Density III - 260,000 eggs/unit (1.41 eggs/cm³)

Inc. 6-4	Inc. 6-5	Inc. 6-8
Lot 8	Lot 8	Lot 8
Loaded 10/11/79	Loaded 10/11/79	Loaded 10/13/79

had been captured in the fyke net. We sampled wild fry when we sampled the incubation units. All samples were preserved in a 5% formalin solution. After 6 weeks, all samples taken on a single day were examined. Fork length and blotted weights were recorded for individual fry.

A development index: $K_D = \frac{10^3/\text{weight (mg)}}{\text{Length (mm)}}$ as used by Bams

(1970, 1972) was computed for individual fry. Additionally, mean length and weight, variance, standard deviation and error, and 95% confidence intervals for weight and length were calculated for each sample.

Fry Marking and Release:

A percentage of the emergent fry was marked by removal of a fin or combination of fins for the purpose of estimating fry to adult survival. Table 2 summarizes the various marked groups evaluated, incubation sources for fry marking, fin marks used for each control and test group, and the release schedule for each group.

Marking procedures followed methods described in the ADF&G Mark-Tag Manual for Salmon (Moberly et al. 1977). Marking quality was monitored by taking a random sample of 20 fish per 2-hour marking period for each marker and by examining the fish for completeness of fin removal. A discount was applied to a clip when 25% or more of the fin was remaining, as described by Bams and Crabtree (1976). The adjusted discount was applied to the total number of fry marked during the examination to obtain a corrected number of validly marked fry.

Fin-clipped fry were held in recovery tanks for 5 - 12 hours prior to release. Dead fry were removed, counted, and subtracted from the release records.

Table 2. Pink salmon fry marking design for evaluating ocean survival of fry released from the Kitoi Bay Hatchery, 1979.

Mark	Treatment	Fry Source	Release Status
Ad Lv	Test - Saltwater Rear	Hatchery Production	Short-term Rear
Ad Rv	Control - Unfed, Volitional Hatchery Release	Hatchery Production	Volitional Release
Rv	Test - Incubation Density III	Density III Incubators	Volitional Release
Lv	Control - Incubation Control for Density III	Hatchery Production	Volitional Release
Lp	Test - Unfed, Volitional Hatchery Release	Hatchery Production	Volitional Release
Rp	Control - Big Kitoi Creek Wild Fry	Big Kitoi Creek	Volitional Release

Marked and unmarked emergent fry were released from the central fry collection system through four polyethylene pipes, 5-cm diameter, which emptied into Big Kitoi Creek below the index nets. All unfed fry released were liberated after dark on a nightly basis. Marked and unmarked fry scheduled for short-term rearing were transported to saltwater pens on a daily basis.

Rearing and Estuarine Studies

Saltwater Rearing:

Emergent pink salmon fry from the production incubation system were enumerated and transferred to saltwater rearing pens within 24 hours after emergence. A portion of the emergent fry was marked and placed in rearing pens with unmarked fry.

Rearing pens, with a volume of 20.4 m³ and made of 0.32-cm mesh, were suspended from a square flotation collar. The mass of fry reared per pen (82 kg of fry/pen) was calculated so that pen densities would not exceed 1.0 kg of fish per 0.125 m³ at the time of release.

Emergent fry were initially fed Oregon Moist starter mash. When active feeding was observed, 1/32" Oregon Moist Pellets were added to the diet in increasing amounts during a 5-day period. All fry were fed at a rate of 5% body weight per day for the entire rearing period.

Growth was monitored on a weekly basis, and feeding schedules were adjusted accordingly. Pen maintenance was performed as required.

Fry were released when they attained a weight judged as suitable for release, and when densities of zooplankton increased within the bay.

Estuarine Studies:

Marine plankton abundance in Kitoi Bay was monitored weekly to predict numbers of food organisms available to juvenile pink salmon. Plankton samples were collected from four stations within the bay (Figure 1). The stations were selected in locations where fry had been observed feeding.

Vertical plankton tows were made at each station with a 30-cm diameter conical net. Tows were made from a depth of 12.2 m to the surface at stations 1, 3, and 4 and 18.3 m to the surface at station 2. Plankton from each station was washed into a 125-ml bottle containing 12.5 ml of formalin.

Samples were analyzed by placing 1-ml subsamples into Sedgewick-Rafter counting cells. A glass slide with two .05-ml test cells was placed over the counting cell, and the number and types of organisms per test cell (five test cells/sample) were identified and enumerated.

Plankton densities per station were computed as the number of plankters per cubic meter by the following formula:

$$\hat{N} = \left(\frac{\sum i}{n} \right) (Y/X) / (D)(A)$$

where \hat{N} = number of plankters per/m³, i = number of plankters per test cell, n = number of test cells analyzed (5), Y = volume of each sample (125 ml), X = test cell volume (.05 ml), D = length of tow in meters, and A = area of net opening. Plankton densities were averaged for all stations and graphed

by sample day to determine trends in food organism abundance. Seawater temperature and salinity data taken at a depth of 1.0 m were recorded for each station per sample day.

Pink salmon fry were captured at random sites within Kitoi Bay with a dip net and preserved in a 10% formalin solution. The stomach contents were removed in the laboratory and examined microscopically to enumerate the food organisms (Appendix B. Tables 4 and 5).

Evaluation of Adult Salmon Returns in 1980

Commercial Catch Sampling:

A portion of the commercial seine catches in the southeastern Afognak management district was sampled for marked, adult pink salmon to estimate hatchery contribution to the commercial fishery (Figure 2). Mixed stock fisheries in statistical areas 252-31 and 252-32 were sampled through the entire seine fishery. Total pink salmon catches were determined from fish ticket data compiled at the end of the season. Commercial catches within Kitoi Bay were also sampled.

Fish in commercial catches were examined individually as they were unloaded onto cannery tenders. We collected data on the location of catches, the total number of fish examined, and the number and types of marks recorded. Whole weight and mid-eye to tail-fork lengths were recorded from a subsample of marked fish.

The estimated contribution of hatchery-produced pink salmon to mixed stock commercial fisheries was calculated by the following formula:

$$\text{Hatchery Contribution} = (\text{Proportion of Hatchery Fish in Catch})(\text{Total Catch})$$

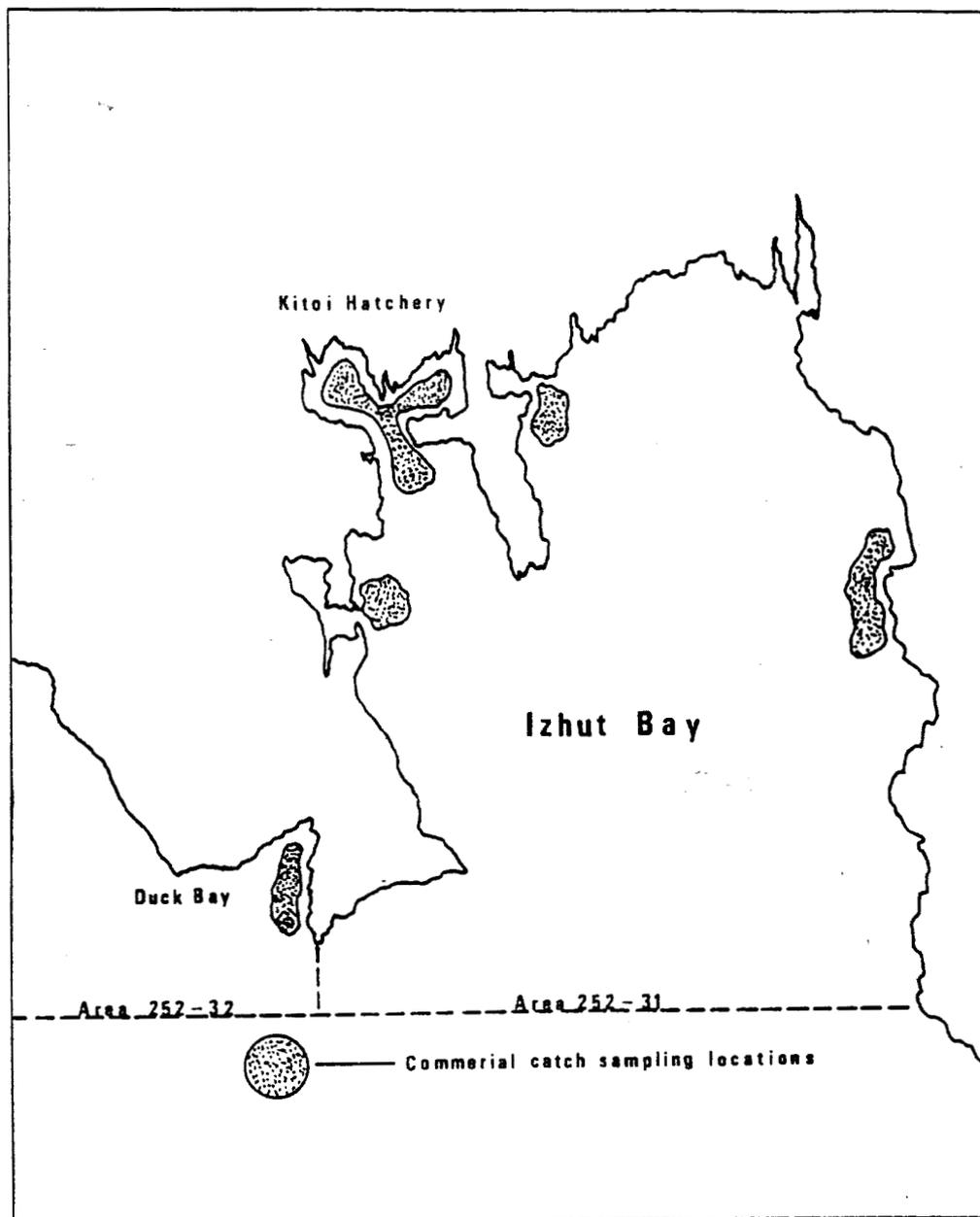


Figure 2. Pink Salmon commercial catch sampling locations where interception of hatchery produced salmon occurred in 1980.

where: Proportion in Catch =

$$\frac{(\text{No. of Hatchery Fish Released}) (\text{No. Marks Recovered})}{(\text{No. of Marked Fish Released}) (\text{No. Adults Sampled})}$$

Marked Adult Recovery at the Hatchery:

All returning pink salmon utilized for hatchery brood-stock were examined for fin marks as they were spawned. Whole weights and mid-eye to tail-fork lengths were recorded from a subsample of the marked fish recovered. Adult pink salmon which passed through the weir into Big Kitoi Creek were not examined.

RESULTS

Incubation and Water Quality

An estimated 22.8 million pink salmon eggs were obtained in 1978. Green-to-eyed-egg survival was estimated at 84.1%, (19,205,400 eggs survived). About 2.6 million eyed eggs were loaded into nine test and three control incubation units at the densities given in Table 1. The remaining 16.6 million eyed eggs were seeded into 95 production incubators at a density of approximately 175,000 eggs per unit.

The higher than expected mortality (15.9%) of green eggs was assumed to have been associated with warm water temperatures in the hatchery during early stages of egg development. Hatchery water temperatures exceeded 14.5°C from 1 September to 6 September (Figure 3). Combs (1965) found that the mortality rate of sockeye salmon (O. nerka) eggs significantly increased at temperatures exceeding 12.8°C. During early cell

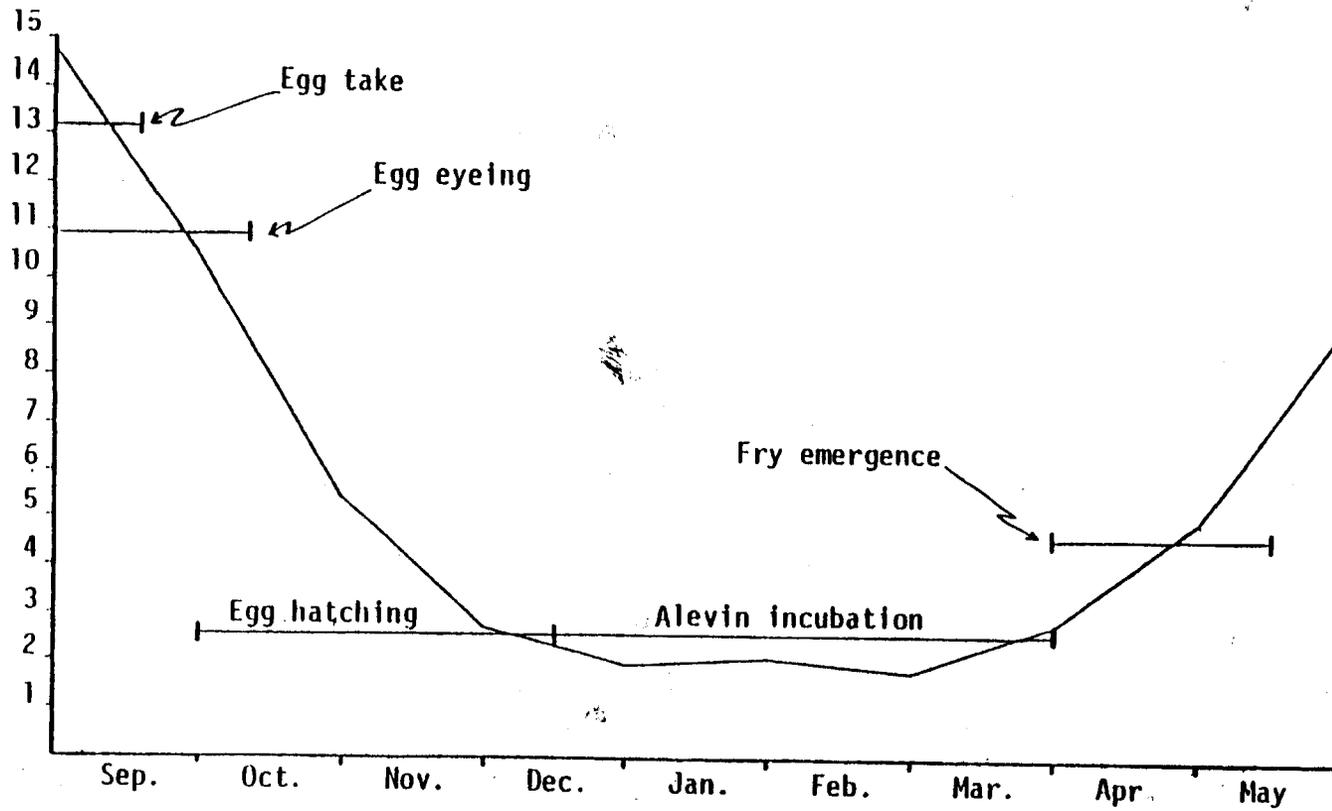


Figure 3. Kitoi Bay Hatchery water temperatures (1978-1979) and time lines of pink salmon egg and alevin development.

development, 55% of the green eggs were incubated in water exceeding 14°C. Green egg to eyed-egg mortality per lot ranged from 10.7% to 24.1%.

Analysis of water quality samples that were collected throughout the incubation period showed that dissolved oxygen remained near the saturation level at all stages of egg and alevin development while only trace concentrations of free carbon dioxide and ammonia were observed (Appendix B. Table 1).

Fry Emergence and Survival

Fry emergence began in early April as hatchery water temperatures approached 3°C (Figure 3). Figure 4 illustrates fry emergence trends by date for all incubation sources except Big Kitoi Creek. Total enumeration of outmigrant creek fry was not feasible, and high water conditions prevented continuous operation of a fyke net to provide a reliable fry emergence index. Relative catch rates of wild fry indicated similar emergence timing to hatchery-incubated fry.

Eyed egg to fry survivals for the incubation test groups and control group are summarized in Figure 4. Survivals in individual control incubators ranged from 76.4% to 94.8%. Survivals in the test units ranged from 92.7% (Density II) to 98.5% (Density II). Total hatchery release, including production from all density tests, was 17.4 million pink salmon fry for an overall eyed egg to fry survival of 90.8% and a green egg to fry survival of 76.3% (Table 3).

Fry Size and Development

Emergent fry from all sources were nearly equivalent in size (Figure 5). Mean length and weight were within a range of 0.5 mm and 12.6 mg, respectively (Table 4, Appendix B. Table 2).

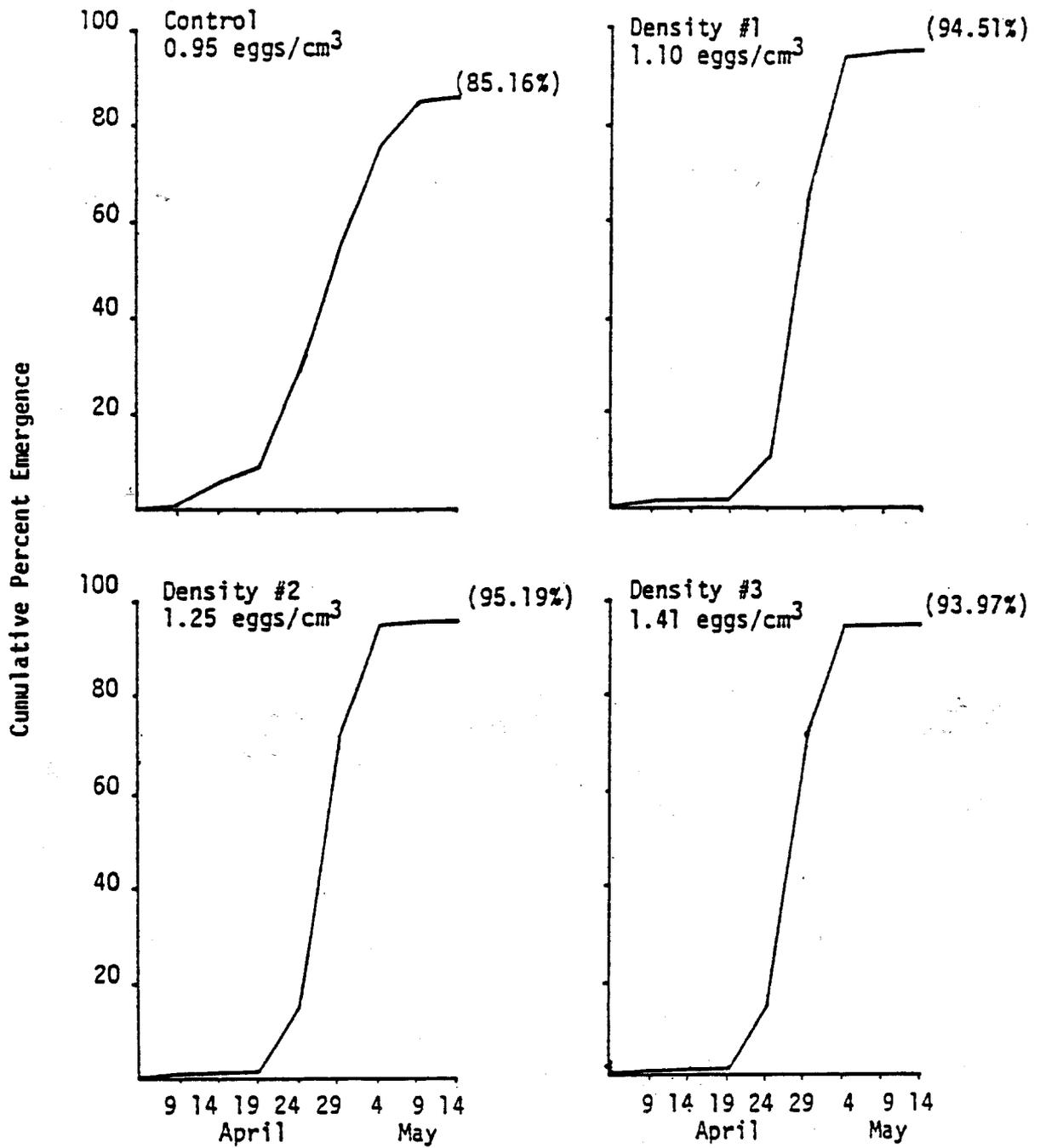


Figure 4. Pink salmon fry emergence timing and eyed-egg to fry survival of four incubation density test groups at the Kitoi Bay Hatchery, 1978-1979.

Table 3. Marked and unmarked pink salmon fry releases from Kitoi Bay Hatchery and Big Kitoi Creek, 1979.

Experiment	Fry Source	Mark	Marked fry release	Total fry release
Test - Saltwater Rear	Hatchery Production	Ad Lv	31,389	3,122,260
Control - Unfed, Volitional Hatchery Release	Hatchery Production	Ad Rv	42,246	5,059,377
Test - Incubation Density III	Density III Incubators	Rv	46,857	730,743
Control - Incubation Control	Hatchery Production	Lv	47,354	5,670,757
Test - Unfed, Volitional Hatchery Release	Hatchery Production	Lp	22,861	2,736,399
Control - Wild Fry	Big Kitoi Creek	Rp	<u>6,425</u>	<u>116,740</u>
			Total:	197,132 17,436,276

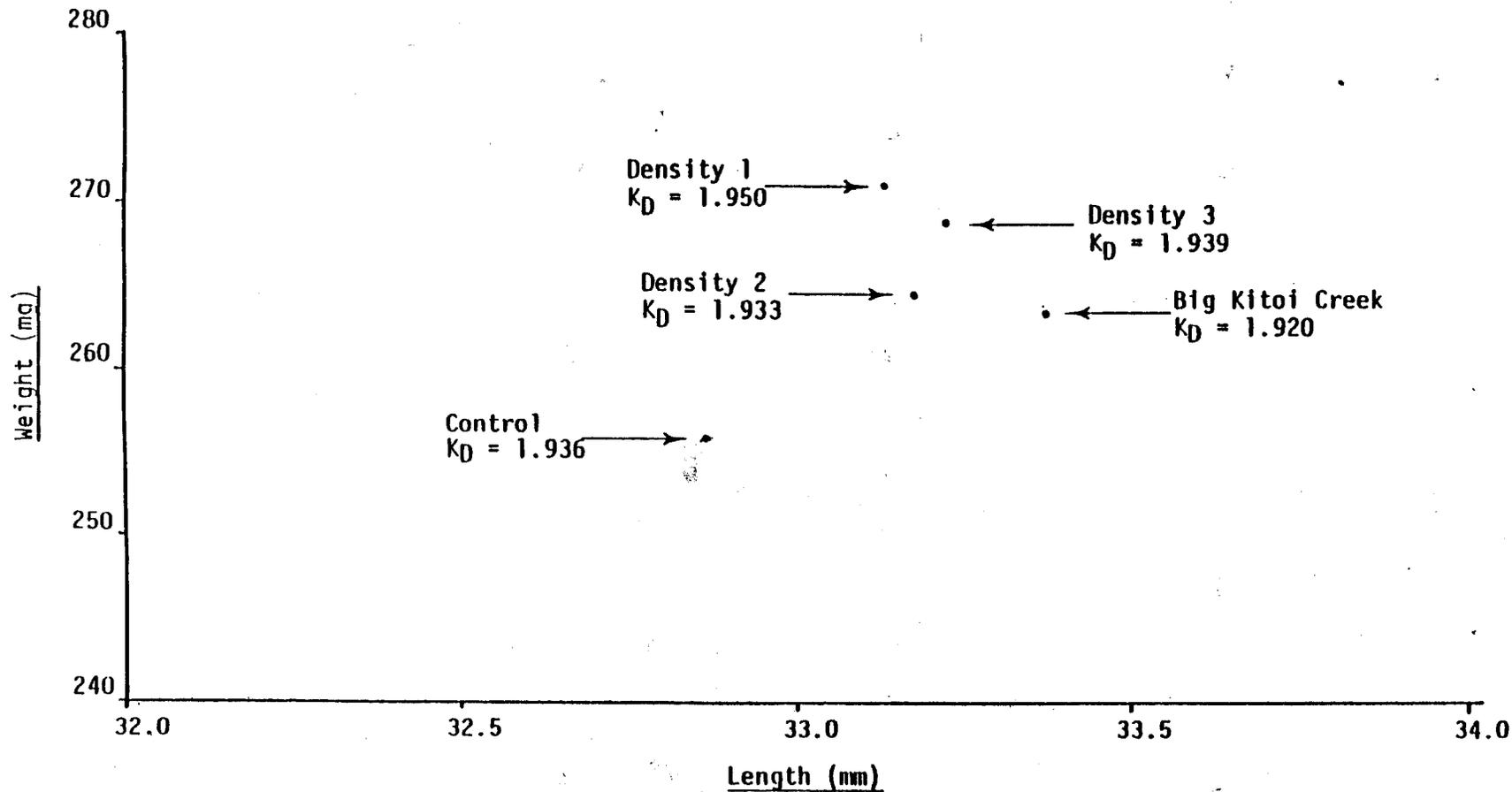


Figure 5. Comparison of mean size and development (K_D) of emergent pink salmon fry from four hatchery incubation sources and Big Kitoi Creek, 1979.

Table 4. Grand means of lengths, weights, and development indices (K_D) of pink salmon fry samples from Big Kitoi Creek and hatchery incubation tests, 1979.

Source	Sample Size	Length (mm)		Weight (mg)		K_D	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Big Kitoi Creek	145	33.4	1.5	263.2	31.7	1.920	.08
Control	447	32.9	1.2	255.9	27.8	1.936	.04
Density I	447	33.1	1.3	270.9	34.0	1.950	.06
Density II	450	33.2	1.1	264.4	29.3	1.933	.04
Density III	449	33.2	1.2	268.5	29.4	1.939	.04

The ratio of weight to length, calculated as a development index (K_D), expresses the increase in fry length and the simultaneous decrease in weight due to yolk sac absorption as emerged, unfed fry become more developed (K_D decreases). Fry from Big Kitoi Creek were slightly more developed than hatchery fry. Wild fry size and development were comparable to data presented by Blackett (1974).

Saltwater Rearing

Approximately 3.2 million emergent fry from the hatchery production system were placed in ten 20.4-m³ saltwater rearing pens located in Kitoi Bay, near the hatchery. Average fry weight at loading was 0.256 g for a calculated average rearing density of 4.02 kg of fry per m³. All fry were reared for approximately 36 days and released on 23 May at an average weight of 0.669 g per fry. Overall mortality during rearing was estimated at 2.56%. The estimated food conversion was 1.79 (total food fed/total biomass gain). Seawater temperatures ranged from 4.0°C to 8.1°C during rearing.

Reared fry that were larger than 0.5 g are typically released in conjunction with increasing densities of zooplankton in the nursery areas. However, in 1979, pen-cultured fry were released prior to an increase in copepod density, although the number of organisms per cubic meter was considerably less than observed during an earlier plankton bloom (Figure 6).

Marine Plankton

The most common food items in stomach samples of pink salmon fry that were captured in Kitoi Bay were copepods, barnacle nauplii, and barnacle cyprids. As determined from fry stomach

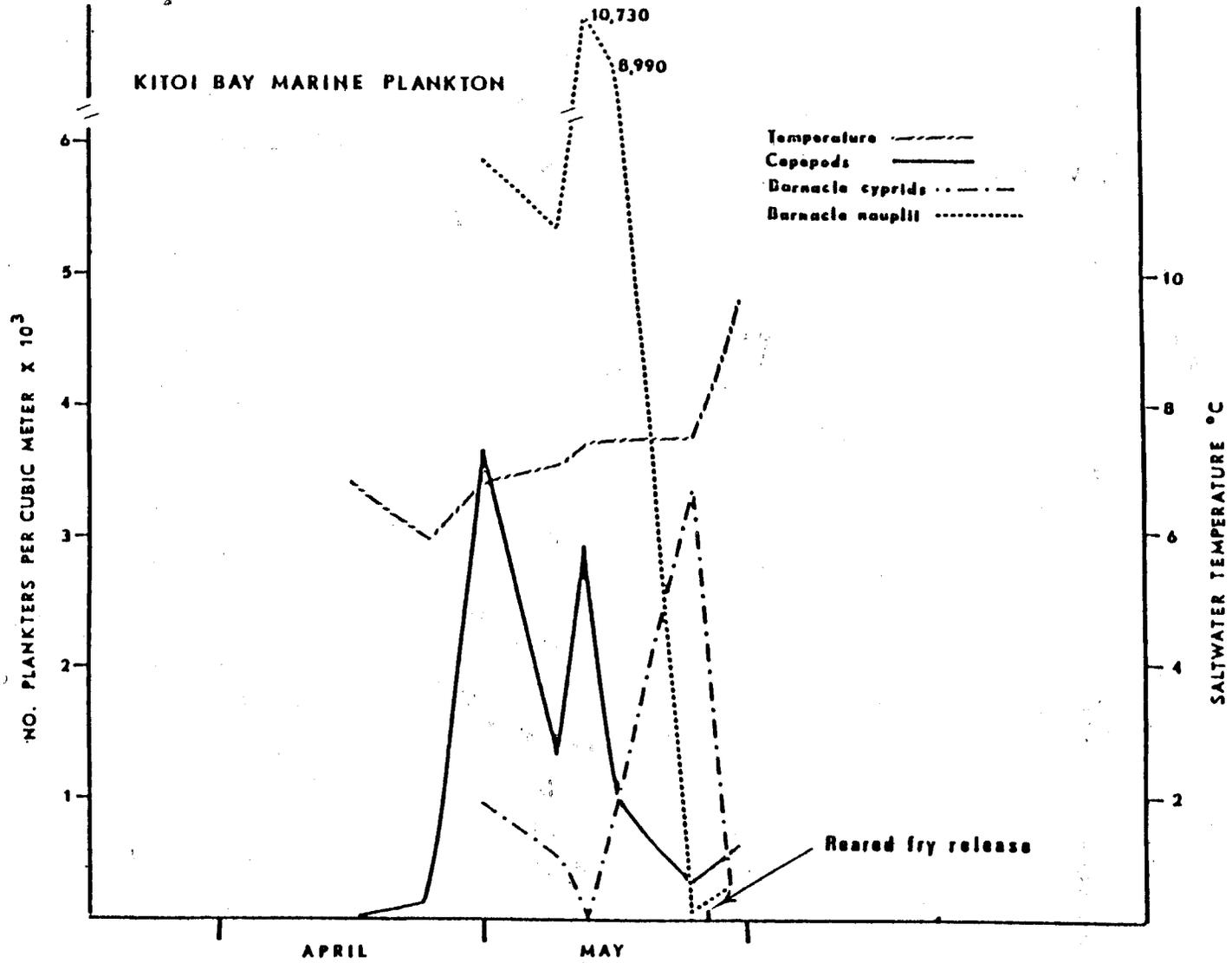


Figure 6. Marine plankton densities and seawater temperatures in Kitoi Bay, 15 April through 30 May, 1979.

contents, these were preferred organisms. Consequently, an increase in these species was used to time the releases of reared fry.

Zooplankton densities were relatively low until late April when a major increase in copepod abundance was observed (Figure 6). Copepod densities peaked near 1 May and 11 May with 3,626 and 2,900 organisms per m³ observed, respectively. Densities declined to 508 organisms per m³ during the last week in May.

Peak emergence of hatchery fry occurred between 24 April and 4 May when large numbers of food organisms were available in Kitoi Bay. Pen cultured fry released on 23 May encountered lower numbers of food organisms, but increasing abundance of copepod nauplii in the 23 May and 29 May plankton samples suggested increases in adult copepod densities in early June.

Kacyznski et al. (1973), Bailey et al. (1975), and Kron and Yuen (1976) found that juvenile pink salmon did not consume various planktonic organisms in proportion to plankton species availability in rearing pens. Limited analysis of fry stomach contents suggests that this was also true for pink salmon fry in Kitoi Bay. On 1 May, plankton samples consisted of 28.1% copepods, 45.5% barnacle nauplii, 7.3% barnacle cyprids, and 19.1% copepod nauplii, hydromedusea, cladocerans, and isopods (Appendix B. Table 3). Stomach contents of fry (n = 10) caught on 2 May were comprised of 70.1% copepods, 17.4% barnacle nauplii, 9.8% barnacle cyprids, and 2.7% amphipods, cumaceans and isopods (Appendix B. Table 4).

Plankton samples collected on 15 May consisted of 7.1% copepods, 62.9% barnacle nauplii, 6.1% barnacle cyprids, and 13.9% copepod; nauplii, gastropod larvae, cladocerans, and cumaceans (Appendix B. Table 3). Stomach contents of fry

(n = 10) caught on 16 May consisted of 93.6% copepods, 1.4% barnacle nauplii, 1.1% barnacle cyprids, and 3.9% cumaceans, cladocerans, amphipods, and invertebrate eggs (Appendix B. Table 5).

Ocean Survival and Adult Returns

Examination for marked adult pink salmon returning from the 1979 release began on 23 July 1980 with the commencement of commercial fishing activities in the east Afognak district and was completed on 15 September with the termination of hatchery egg-take activities. A total of 244,000 pink salmon were examined for marks (fishery and hatchery brood-stock) with a recovery of 929 marked fish. Commercial catches were sampled throughout the entire season in three primary interception areas for pink salmon returning to Kitoi Bay.

In the Duck Bay (251-32) and Izhut Bay (251-31) areas, catches were comprised of hatchery, Big Kitoi Creek, and native stocks from systems on Afognak and Kodiak Islands. The terminal fishery inside Kitoi Bay was comprised of hatchery and wild fish from Big Kitoi Creek. The estimated contribution of hatchery- and creek-produced pink salmon to commercial catches and adult returns to the facility are summarized in Table 5.

Fry to adult survival of hatchery- and creek-produced pink salmon was calculated from the ratio of marked adults in the return versus the number of validly marked fry released per incubation source. The methods for this, described in Appendix A, were applied to mark recovery data to correct for differential marking mortality between pectoral and ventral clips and differential mortality between marked and unmarked groups. The average ocean survival of unfed volitionally released hatchery fry was 1.89% with a range of 1.62% to 2.02% (Table 6). The combined unfed, volitional-release groups

Table 5. Summary of Kitoi Bay Hatchery and Big Kitoi Creek pink salmon production, commercial catch contribution, and return to the facility, 1978 brood.

Contribution Source	Hatchery Production (± 80 CI)	Natural Production (± 80 CI)	Total Return	Range @ 95% C.I.
Mixed stock fisheries	153,974 (±17,654)	1,351 (±527)	155,325	137,144 - 173,506
Kitoi Bay catches	123,580	1,085 (±241) ^{a/}	124,665 ^{b/}	---
Broodstock and escapement	83,671	725 (±120) ^{a/}	83,396 ^{b/}	---
	360,225 (±17,654)	3,161 (±888)	363,386	344,844 - 381,928

^{a/} Estimates based on fin mark recoveries.

^{b/} Actual catch and return data derived from fish tickets and hatchery records, respectively.

Table 6. Estimated ocean survival of various groups of pink salmon fry released from the Kitoi Bay Hatchery and Big Kitoi Creek, 1979.

Release Group	Mark	Number of Fry Released	Number of Adults Returning	Percent Ocean Survival
Saltwater reared	Ad Lv	3,120,000	87,800	2.81
Unfed Volitional release	Ad Rv	5,060,000	81,900	1.62
Density III	Rv	731,000	19,000	2.61
Unfed Volitional release	Lv	5,670,000	115,300	1.62
Big Kitoi Creek	Rp	117,000	55,200	2.02
Unfed Volitional release	Lp	2,740,000	3,160	2.71

totalled 77.2% of the hatchery release and 69.7% of the adult return. Ocean survival was 2.71% for wild fry from Big Kitoi Creek and 2.81% for short-term reared fish. A single incubation density test (Density III, 1.41 eggs/cm³ of substrate), in which we evaluated all life stages through the adult return, resulted in fry to adult survival of 2.61%.

A chi-square statistic corrected for continuity (Snedecor and Cochran, 1967) was calculated for each incubation and release experiment to test for significant differences in marine survival of fry released from the test and control groups (Table 7). For each experiment the chi-square value was calculated from the observed and expected frequencies of fin marks that were found and not found in the adult return.

The size of returning adults varied only slightly between the reared and density test groups and the corresponding control groups (Table 8). Returning adults from the short-term reared group were slightly smaller than adults from the control group, as was the case with rearing studies conducted by Martin et al. (1981). Both sexes from the Big Kitoi Creek were smaller than all other groups measured. The smaller size of fish in these groups may have been caused by the pectoral mark.

DISCUSSION

Based on the results of incubation tests evaluating egg to fry survival and fry development, Kitoi incubation units can be operated at eyed egg densities up to 1.41 eggs per cm³ of substrate. Theoretically, the units could be operated at higher densities since none of the measured physical parameters have indicated signs of environmental stress to incubating alevins or emergent fry. Fry that were released

Table 7. Summary of chi-square calculations to test for significant differences in marine survival for three pink salmon fry release experiments, Kitoi Bay Hatchery, 1979.

Experiment	Estimated Marine Survival %	Calculated chi-square	Decision
Saltwater Reared Fry versus Unfed, Volitional Hatchery Released Fry	2.81	11.53	Significant difference in survivals ($p < .01$)
Incubation Density III, released unfed versus Production Incubation Density, released unfed	2.61	2.01	No significant difference in survivals
Big Kitoi Creek Wild Fry versus Unfed, Volitional Hatchery Released Fry	2.71	6.56	Significant difference in survivals ($.01 < p < .05$)
	2.02		

Table 8. Mean lengths and weights of marked adult pink salmon recovered from commercial catches and hatchery brood-stock, Kitoi Bay, 1980.

Treatment	Mark	Sample Size	Mean Length (cm)	Mean Weight (kg)
<u>MALE</u>				
Test - Saltwater rear	Ad Lv	46	44.0	1.40
Control - Unfed volitional hatchery release	Ad Rv	51	44.5	1.46
Test - Incubation Density III	Rv	76	44.4	1.43
Control - Incubation Control for Density III	Lv	77	43.9	1.42
Test - Unfed volitional hatchery release	Lp	24	42.1	1.09
Control - Big Kitoi Creek wild fry	Rp	15	42.3	1.11

- Continued -

Table 8. Continued.

Treatment	Mark	Sample Size	Mean Length (cm)	Mean Weight (kg)
<u>FEMALE</u>				
Test - Saltwater rear	Ad Lv	35	45.0	1.39
Control - Unfed volitional hatchery release	Ad Rv	34	45.3	1.44
Test - Incubation Density III	Rv	47	45.2	1.42
Control - Incubation Control for Density III	Lv	46	45.5	1.44
Test - Unfed volitional hatchery release	Lp	19	43.9	1.25
Control - Big Kitoi Creek wild fry	Rp	11	43.8	1.22

from the high density incubation group survived in the ocean at a higher rate of ocean survival than fry from the corresponding control group. Although the chi-square test did not show a significant difference.

Incubation density tests demonstrate that the production capacity of the Kitoi Bay Hatchery can be increased from 21 million to 31 million eggs annually without modifying the present incubation system. Additional testing will probably indicate that the facility production capacity can be increased further.

As shown by the results of pen culture studies, short-term saltwater rearing will significantly increase the ocean survival of hatchery-produced pink salmon. Although fry release timing undoubtedly influences ocean survival, rearing experiments at Kitoi Bay to date have not been specific enough to quantify the effects of releasing reared fry at different levels of estuarine productivity. Moreover, the concept of "optimal release timing" has not been defined effectively. Comprehensive rearing studies, similar to those conducted by Martin et al. (1980) at Little Port Walter, would provide quantitative information concerning release timing of fry reared at the Kitoi Bay facility.

Marine plankton densities, specifically densities of preferred food organisms such as copepods, are general indicators of estuarine feeding conditions. Since observations of marine plankton densities began in 1976, releases of pink salmon fry that were reared for 30 to 40 days have generally coincided with increasing densities of preferred food organisms that occur near the end of May. Based on the consistent trend in marine plankton blooms, the hatchery manager can plan food requirements and fry releases accordingly.

The analyses of pink salmon fry stomach contents, in relation to standing crops of marine zooplankton, indicate that juvenile pink salmon in Kitoi Bay are selective grazers with a preference for copepods. Studies have shown that zooplankton densities generally do not begin to increase until the later part of April. Outmigrant hatchery fry begin entering the estuary in early April and normally encounter poorer feeding conditions than those of the late hatchery-released or short-term reared fry. A 2-week minimal rearing period for all hatchery fry, with releases scheduled on a weekly basis, would distribute large hatchery releases of pink salmon fry over time, and would, theoretically, buffer the impact on standing crops of preferred food organisms as well as delaying the seaward migration slightly so that hatchery-produced fry would encounter improved feeding conditions in the estuary. This assumes that pen-reared fry will remain in Kitoi Bay and exhibit similar feeding habits as the fry analyzed in this study. This assumption needs to be verified.

The results of the recovery program for marked adults clearly illustrate that salmon production in the east Afognak fishing district has been enhanced as a result of pink salmon fry releases from the Kitoi Bay Hatchery. Hatchery contributions have provided supplemental production to mixed stock cape fisheries as well as additional fleet fishing opportunities through the terminal harvest of pink salmon in Kitoi Bay.

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A P P E N D I X A

A METHOD OF ANALYSIS FOR ALLOCATION OF MARKED
AND UNMARKED PINK SALMON RETURNS AT KITOI BAY

Step 1. Calculates the handicap for pectoral fin clips when both ventral and pectoral clips are used.

$$\frac{\text{Ventral clip recovery}}{\text{No. marked fry released}} = \text{Marked return}$$

$$\frac{\text{Rv } 90}{\text{Rv } 25,025} \times 100 = .0036$$

$$\frac{\text{Pectoral clip recovery}}{\text{No. marked fry released}} = \text{Marked return}$$

$$\frac{\text{Rp } 18}{\text{Rp } 12,853} \times 100 = .0014$$

Marked return ventral clip - marked return pectoral clip = Handicap

$$\text{Rv } .0036 - \text{Rp } .0014 = .0022 \text{ Handicap}$$

Handicap + pectoral clip marked return = Adjusted pectoral clip return

$$.0022 + .0014 = .0036$$

Adjusted pectoral clip return x No. marked fry released = Adjusted No. pectoral clip fish recovered.

$$.0036 \times 12,853 = 46$$

When an experiment or evaluation requires the use of ventral and pectoral fin clips in a comparison of survival, it is necessary to evaluate differential mortality between fin clips. The same fry source and equivalent marking, handling, and release must be used for the pectoral and ventral fin clip group when they are used to determine differential mortality. The assumption is made that there is no difference between right and left fin clips. This allows either a right or left pectoral fin to be clipped for a test and leaves the remaining fin available for determining differential mortality. Evaluation of double clips (i.e. both ventrals) is impossible by this method.

Step 2. After adjustments of pectoral fin clip returns (step 1), calculate the percent of marked fish in all fish examined and the number of marked fish in the return for each clip group.

$$\frac{\text{Number of marked fish recovered}}{\text{Number of fish examined}} \times 100 = \% \text{ marked}$$

$$\text{AdLV} \frac{84}{69,594} \times 100 = 0.12\%$$

$$\text{AdRV} \frac{41}{69,594} \times 100 = .06\%$$

$$\text{Lv} \frac{78}{69,594} \times 100 = 0.11\%$$

$$\text{Rp} \quad \frac{46}{69,594} \times 100 = .07\%$$

Etc.

Commercial Catch + Broodstock & Mortality + Big
Kitoi Creek escapement = Total Return

$$180,057 + 39,276 + 15,988 = 235,321$$

% Marked of those examined x Total return = Marked
fish in return

$$\begin{aligned} \text{-AdLV} & .0012 \times 235,321 = 282 \\ \text{AdRV} & .0006 \times 235,321 = 141 \\ \text{LV} & .0011 \times 235,321 = 259 \\ \text{Rp} & .0007 \times 235,321 = 165 \end{aligned}$$

Etc.

This step projects the actual percent recovery for each
fin clip recovered to the total return. The result is a
projected number of marked fish for each fin clip in the
total return.

Step 3. Calculates the percent return of marked fry released
using the total marked fish of each group in the
total return.

$$\frac{\text{Total marked fish in return}}{\text{Marked fry released}} \times 100 = \% \text{ Return}$$

$$\text{AdLV} \quad \frac{282}{31,658} \times 100 = 0.89\%$$

$$\text{AdRV} \frac{141}{18,996} \times 100 = 0.74\%$$

$$\text{LV} \frac{259}{31,791} \times 100 = 0.81\%$$

$$\text{Rp} \frac{165}{12,853} \times 100 = 1.28\%$$

Etc.

This is the percent of marked fry of each fin clip group projected to be in the total return.

- Step 4. Calculates the return expected from the total fry released from each incubation source.

% Marked in return x Total fry released = Expected return

$$\text{AdLV} \quad 0.89 \times 1,851,604 = 16,479$$

$$\text{AdRV} \quad 0.74 \times 703,349 = 5,205$$

$$\text{LV} \quad 0.81 \times 12,713,211 = 102,977$$

$$\text{Rp} \quad 1.28 \times 12,961 = 166$$

Etc.

The sum of the expected return for each incubation source is the total expected return i.e.:

$$16,479 + 5,205 + 102,977 + 166 + \text{etc.} = 158,622$$

The expected return is projected directly from marked fish recovery. The known return in 1979 of 235,321 is 76,699 fish greater than the expected

return of 158,622. The reason for this is that marked fish have a substantially higher mortality than unmarked fish. A handicap ratio for marked pink salmon of 37-49% was observed in experiments reviewed by Ricker (1976). Steps 5 & 6 adjust for this mortality factor.

Step 5. Calculates the percent contribution of each source to the total expected return.

$$\frac{\text{Return for each source}}{\text{Total expected return}} \times 100 = \% \text{ Contribution to return}$$

$$\text{AdRV} \quad \frac{16,479}{158,622} \times 100 = 10.39\%$$

$$\text{AdRV} \quad \frac{5,205}{158,622} \times 100 = 3.28\%$$

$$\text{LV} \quad \frac{102,977}{158,622} \times 100 = 64.92\%$$

$$\text{RP} \quad \frac{166}{158,622} \times 100 = 0.10\%$$

Etc.

Step 6. Calculates the adjusted contribution of each source to the total return.

$$\% \text{ contribution} \times \text{Total return} = \text{Adjusted source contribution}$$

$$\begin{aligned}
\text{AdLV} & 0.1039 \times 235,321 = 24,450 \\
\text{AdRV} & .0328 \times 235,321 = 7,718 \\
\text{LV} & 0.6492 \times 235,231 = 152,770 \\
\text{Rp} & .0010 \times 235,321 = 235
\end{aligned}$$

Etc.

Step 7. Calculates % recovery (survival) for each source contributing to the total return.

$$\frac{\text{Adjusted source contribution}}{\text{Number of fry released}} \times 100 = \% \text{recovery(survival)}$$

$$\text{AdLV} \quad \frac{24,449}{1,851,604} \times 100 = 1.32\%$$

$$\text{AdRV} \quad \frac{7,718}{703,349} \times 100 = 1.10\%$$

$$\text{LV} \quad \frac{152,765}{12,713,211} \times 100 = 1.20\%$$

$$\text{Rp} \quad \frac{235}{12,961} \times 100 = .81\%$$

Etc.

The following must be known at Kitoi:

1. Total number of fry released from each incubation source contributing to the return. This includes natural production.

2. Total number of valid marked fry released from each incubation source contributing to the return.
3. An estimate of total salmon return.

The following assumptions are accepted:

1. No difference in mortality between right and left clips of paired fins.
2. Ratio of marked fish recovered truly represents the ratio in the total return.
3. Commercial fishery is non-selective of marked and/or unmarked fish.

The following are sources of error:

1. Regeneration of fins. Regeneration of clipped ventral fins on pink salmon fry held in saltwater pens at Kitoi for 6 months resulted in 30% of the marks being unidentifiable.
2. Failure to detect marked fish equivalently during recovery examination, i.e. adipose fin clip not detected as easily as pelvic fin clip.
3. Pre-emergent fry index estimator of natural creek fry production in error.
4. Failure of the hatchery to accurately assess number of fry released for each source represented by a fin clip.

5. Inadequate recovery of marked fish in the fishery (area and number of fish examined).
6. Inaccurate total return estimate.
7. Failure in the marking design to treat all groups of marked fry equivalently.

APPENDIX A. REFERENCES

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A P P E N D I X B

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Appendix B. Table 1. Range of water chemistry at the Kitoi Bay Hatchery during incubation studies, 1978-1979.

<u>Water Chemistry</u>						
Source	Dissolved O ₂ (ppm)		Free CO ₂ (ppm)		Ammonia	
<u>November 1978</u>						
Control	12.5	- 13.1	2.0	- 3.5	Trace	
Density I	12.0	- 12.8	2.0	- 3.5	Trace	
Density II	11.8	- 13.1	2.0	- 2.5	Trace	
Density III	12.0	- 13.1	2.0	- 2.5	Trace	
<u>December 1978</u>						
Control	13.9	- 14.2	0.15	- 2.0	Trace	
Density I	12.5	- 14.6	0.20	- 2.5	Trace	
Density II	13.9	- 14.2	0.25	- 2.5	Trace	
Density III	13.9	- 14.4	0.20	- 2.0	Trace	
<u>January 1979</u>						
Control	13.8	- 14.8	2.0	- 2.5	Trace	
Density I	13.5	- 14.4	1.5	- 3.0	Trace	
Density II	13.8	- 14.4	1.5	- 3.0	Trace	
Density III	13.6	- 14.4	2.0	- 3.0	Trace	

- Continued -

Appendix B. Table 1. Continued.

<u>Water Chemistry</u>						
Source	Dissolved O ₂ (ppm)		Free CO ₂ (ppm)		Ammonia	
<u>February 1979</u>						
Control	14.4	- 14.8	1.8	- 2.0	Trace	
Density I	13.2	- 14.2	2.0	- 2.5	Trace	
Density II	13.8	- 14.2	1.5	- 2.0	Trace	
Density III	13.5	- 14.2	1.5	- 2.5	Trace	
<u>March 1979</u>						
Control	12.8	- 14.8	2.0	- 3.0	Trace	
Density I	11.8	- 13.8	2.0	- 4.0	Trace	
Density II	12.0	- 13.6	2.5	- 4.5	Trace	
Density III	12.2	- 13.8	2.5	- 3.5	Trace	
<u>April 1979</u>						
Control	13.0		2.0	- 2.5	Trace	
Density I	12.4	- 12.8	2.0	- 3.0	Trace	
Density II	12.5	- 12.8	2.0	- 2.5	Trace	
Density III	12.4	- 12.6	2.0	- 2.5	Trace	

Appendix B. Table 2. Mean lengths, weights, and development indices (K_D) of emergent pink salmon fry by sample date and source at the Kitoi Bay Hatchery, 1979.

Source	Collection Date	Sample Size	Length (mm)		Weight (mg)		K_D Index	
			Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Big Kitoi Creek	4/24	47	33.3	2.2	266	26	1.935	0.14
	4/26	48	33.3	1.2	255	31	1.900	0.05
	5/01	50	33.5	1.2	269	38	1.924	0.06
Control Inc. 4 ₁₅	4/24	50	33.5	1.2	251	25	1.939	0.042
	4/25	50	33.3	1.0	251	24	1.889	0.032
	4/30	50	32.6	1.2	253	26	1.941	0.029
Inc. 5 ₂	4/24	47	32.7	1.3	248	29	1.921	0.058
	4/25	50	32.3	1.3	245	26	1.938	0.044
	4/27	50	32.7	1.3	261	29	1.952	0.032
Inc. 4 ₉	5/2	50	33.3	1.3	270	29	1.942	0.041
	5/4	50	32.7	1.1	264	31	1.960	0.045
	5/6	50	32.8	1.3	260	31	1.944	0.035

- Continued -

Appendix B. Table 2. Continued

Source	Collection Date	Sample Size	Length (mm)		Weight (mg)		K _D Index	
			Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Density - 200,000	4/26	49	32.9	1.0	268	23	1.956	0.036
Inc. 6 ₁	4/27	50	33.1	1.5	271	39	1.950	0.045
	4/30	50	32.9	1.7	271	41	1.960	0.049
Inc. 6 ₃	4/26	50	33.4	1.3	272	32	1.939	0.038
	4/27	49	33.5	1.5	276	38	1.940	0.055
	4/30	49	32.9	1.9	268	38	1.959	0.126
Inc. 6 ₇	4/26	50	33.3	1.2	268	33	1.932	0.045
	4/28	50	33.0	1.0	272	32	1.962	0.057
	4/30	50	33.2	1.1	273	30	1.953	0.040
Density - 230,000	4/25	50	33.6	0.9	258	27	1.891	0.043
Inc. 6 ₆	4/26	50	33.3	1.1	267	29	1.930	0.040
	4/28	50	32.9	0.9	267	29	1.957	0.049

- Continued -

Appendix B. Table 2. Continued

Source	Collection Date	Sample Size	Length (mm)		Weight (mg)		K _D Index	
			Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Inc. 6 ₂	4/26	50	33.3	1.4	263	33	1.923	0.040
	4/27	50	32.9	1.2	261	31	1.937	0.040
	4/30	50	33.2	1.2	270	28	1.943	0.035
Inc. 6 ₉	4/26	50	33.6	1.2	266	29	1.911	0.047
	4/27	50	33.0	1.2	270	30	1.957	0.047
	4/30	50	32.7	1.3	257	29	1.944	0.044
Density - 260,000	4/25	50	33.4	1.2	261	32	1.907	0.049
Inc. 6 ₄	4/27	50	33.0	1.2	269	29	1.955	0.048
	4/28	50	33.0	1.5	266	34	1.945	0.037
Inc. 6 ₈	4/25	50	33.8	1.0	263	27	1.895	0.032
	4/27	50	33.3	1.3	273	37	1.945	0.037
	4/28	50	33.0	1.3	267	28	1.948	0.039
Inc. 6 ₅	4/26	49	33.7	1.1	279	24	1.935	0.045
	4.27	50	32.8	1.2	269	30	1.964	0.037
	4/30	50	33.1	1.3	271	26	1.957	0.048

Appendix B. Table 3. Mean number of plankters/m³ and percent composition of marine plankton for all stations combined in Kitoi Bay, 1979.

	04/09/79		04/16/79		04/23/79		05/01/79		05/08/79	
	No.	%								
Copepods			72	4.32	145	18.19	3626	28.10	1305	11.92
Copepod nauplii	1087	59.99	1015	60.89	362	45.42	2171	16.83	2030	18.54
Barnacle nauplii							5873	45.52	5366	45.52
B. cyprids							943	7.31	508	4.64
Gastropod larvae	652	36.04	218	13.08					508	5.30
Hydro-medusans			290	17.40	290	36.39	145	1.12	652	5.96
Euphasid larvae			72	4.32						
Cladocerans	72	3.97					72	0.56		
Polychaete larvae									435	3.97
Mysids									72	0.66
Isopods							72	0.56		
Cumaceans										
Rotifers										

- Continued -

Appendix B. Table 3. Continued.

	05/11/79		05/15/79		05/23/79		05/29/79	
	No.	%	No.	%	No.	%	No.	%
Copepods	2900	15.15	1015	7.11	580	3.10	580	11.76
Copepod nauplii	2030	10.60	1668	11.68	1812	19.38	2900	58.82
Barnacle nauplii	10732	56.07	8992	62.95	72	0.77	290	5.88
B. cyprids			870	6.09	3335	35.66	290	5.88
Gastropod larvae	870	4.54	1595	11.17	798	8.53	798	16.19
Hydro-medusans	2320	12.12			798	8.52	72	1.46
Euphasid larvae								
Cladocerans			72	0.50				
Polychaete larvae					72	0.77		
Mysids								
Isopods	290	1.51			72	0.77		
Cumaceans			72	0.50				
Rotifers							2102	22.48

Appendix B. Table 4. Stomach contents of pink fry caught in Kitoi Bay, 2 May, 1979.

Sample	Harpacticoid		Copepods		Unidentified		Barnacle		Cyprids		Others
	No.	%	No.	%	No.	%	No.	%	No.	%	
1	20	39.21	15	29.41	8	15.68	6	11.76			Amphipods: 2, 3.92%
2	32	52.45	8	13.11	14	22.95	1	1.63	2	3.27	Amphipods: 2, 3.27%, Cumacean: 1, 1.63%, Isopod: 1, 1.63%.
3	21	63.64	2	6.06	Many shells						
4	13	43.33	3	10.0	Many--digested beyond recognition		10	33.33			4 13.33
5	4	36.36	2	18.18			5	45.45			

- Continued -

Appendix B. Table 4. Continued.

Sample	Harpacticoid		Copepods				Barnacle		Cyprids		Others
	No.	%	No.	%	No.	%	No.	%	No.	%	
6			5	55.56	4	44.44					
											(digested)
7	10	66.66	2	13.33			3	20.00			
8	21	87.50	2	8.33							Cumacean: 1, 4.17%.
9	1	25.0					1	25.0	2	50.0	
10	3	37.50	1	12.50			1	12.50	2	25.0	Shrimp, 1, 12.50%.

Summary of % composition:

Copepods	- 70.12%
B. nauplii	- 17.39%
B. cyprids	- 9.77%
Other	- 2.72%

Appendix B. Table 5. Stomach contents of fry caught in Kitoi Bay, May 16, 1979.

Sample	Copepods				Barnacle				Cumaceans	Others and Comments				
	Harpacticoids No.	%	Calanoids No.	Unidentified No.	Nauplii No.	Cyprids No.	Cumaceans No.	Others and Comments						
1	90	75.0	25	20.83				5	4.16					
2	9	19.56	8	17.39				26	56.52	Cladocerans: 3,6.52				
3	103	88.79	10	8.6			1	0.86		Amphipod: 2, 1.7%				
4	62	77.5	6	7.5	2 ¹	2.5	6	3.7	1	1.2	3	3.7		
5	74	85.05					3	3.4	7	8.04			Amphipod, shrimp, mysid: 3.3%	
6	88	92.6	3	3.1			3	3.1	1	1.0				
7	60	35.29	10	5.88	100 ²	58.52								Many invertebrate eggs
8	48	94.12							1	1.96	2	3.92		
9	13	18.31	3	4.23	50 ²	70.42	4	5.63	1	1.41				Many invertebrate eggs
10	70	24.65	14	5.99	200 ²	70.42								Few invertebrate eggs

Summary of % composition:

Copepods	-	93.57%
B. nauplii	-	1.43%
B. cyprids	-	1.07%
Other	-	3.93%

¹ Unidentified because of digestion.

² These are small nauplii and metanaplii stages, appear to be copepods, many of which are gravid.

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