Puntledge River Project 1972 - 1977

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February 1979

Fisheries and Marine Service Technical Report No. 842

Fisheries and Environment Canada / Pêches et Environnement Canada

Fisheries and Marine Service / Service des pêches et de la mer

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PUNTLEDGE RIVER REPORT 1972 - 1977

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Technical Report Series

SALMON ENHANCEMENT BRANCH

PACIFIC REGION

APRIL 1978

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1090 W. Pender
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ABSTRACT

MacKinnon, C.N., H. Genoe, and D.C. Sinclair. 1979. Puntledge River Project 1972 - 1977. Fish. Mar. Serv. Tech. Rep. 842: 126pp.

The biological program at the Puntledge River originated in 1953 when the British Columbia Power Commission initiated a project expanding hydro-electric facilities on the river. The project created several fisheries problems which led initially to the decline of the native summer chinook run and later to the decline of the native fall chinook run. Since that time a spawning channel built in 1965 and a hatchery facility initiated in 1972 have been added to the system in an attempt to mitigate the fisheries problems associated with hydro-electric development. Although the spawning channel may be credited with maintaining the valuable summer chinook population, it has done little to rebuild the species to its previous population level and was subsequently replaced by a rearing and adult holding channel in 1977.

Releases of hatchery incubated and reared summer and fall chinook salmon since 1972 are beginning to show success in their returns to the fishery and the river. Coho salmon were added to the hatchery program in 1976 in an attempt to rehabilitate and enhance coho stocks in the Puntledge River. While propagation of coho to the smolt stage promised success, a need for further work into both the incubational and rearing requirements of steelhead was obvious. Hopefully, the addition of steelhead to the hatchery program coupled with an effective management program of the natural production will rectify the declining steelhead stocks.

In addition to existing facilities, the addition of new facilities at both the diversion dam site and the powerhouse site (1978-1979) should increase production capacity to approximately 5.0 million chinook smolts, 0.6 million coho smolts, and 75,000 steelhead smolts. These facilities are designed to

ABSTRACT (Cont'd.)

build the runs beyond their former level of abundance to achieve a higher and more stable population level to accomodate the needs of the commercial and sport fisheries.

RÉSUMÉ

MacKinnon, C.N., H. Genoe, and D.C. Sinclair. 1979. Puntledge River Project 1972-1977. Fish. Mar. Serv. Tech. Rep. 842: 126pp.

Le programme biologique de la rivière Puntledge a vu le jour en 1953, année où la British Columbia Power Commission a lancé un projet concernant l'expansion des installations hydroélectriques construites sur la rivière. Ce project a perturbé les pêcheries de diverses manières, en mettant d'abord en difficulté la remonte estivale du saumon quinnat local, puis en provoquant le déclin de la remonte automnale de cette même espèce. Depuis lors, on a construit en 1965 un chenal de fraie, puis une piscifacture a été mise en chantier en 1972 afin de tenter d'enrayer les problèmes causés par les installations hydroélectriques. Bien qu'on puisse reconnaître au chenal de fraie le mérite d'avoir permis à la précieuse population de saumon quinnat d'été de se maintenir, il n'a guère contribué à rétablir les stocks à leur niveau antérieur, aussi l'a-t-on remplacé en 1977 par un bassin d'élevage et un vivier.

Les progrès notés dans la pêche locale et l'amélioration de la rivière commencent à montrer l'effet positif des libérations de saumons quinnats d'été e d'automne, incubés et élevés dans la piscifacture, qui ont lieu depuis 1972. Pour tenter de rétablir et de mettre en valeur les stocks de saumon coho de la rivière Puntledge, on a entrepris d'élever également cette espèce. S l'on prévoit un certain succès dans la production de tacons de coho, il faudra poursuivre la recherche en ce qui concerne l'incubation et l'élevage de la truite arc-en-ciel. On espère cependant arrêter le déclin de cette espèce en l'incluant dans le programme de salmoniculture et en améliorant la gestion de la production naturelle.

RÉSUMÉ (Cont'd)

L'addition de nouvelles installations de salmoniculture à l'emplacement du barrage de dérivation ainsi qu'à la centrale (1978-1979) devrait permettre d'atteindre une capacité de production d'environ cinq millions de tacons de saumon quinnat, 600,000 tacons de coho et 75,000 truitelles arc-en-ciel. L'objectif de ces travaux est d'amener les remontes à un niveau supérieur à ce qu'il était auparavant, afin de stabiliser les populations à un taux élevé et de répondre ainsi aux besoins de la pêche commerciale et sportive.

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INTRODUCTION

The biological program at the Puntledge River originated in 1953 when the British Columbia Power Commission (now the British Columbia Hydro and Power Authority) initiated a project expanding hydro-electric facilities on the river. The project created several fisheries problems which led initially to the decline of the native summer chinook run and later to the decline of the native fall chinook run.

The expanded project commenced operation in March, 1955, with the final construction being completed in early 1958. Water diversion for power generation was increased from a former maximum of approximately 300 C.F.S. to a maximum of 1,000 C.F.S. The facilities include an impounded dam at the outlet of Comox Lake, a diversion dam and intake works located about 4.0 miles below the lake where flow entering a single penstock, is carried through a powerhouse which discharges the flow through its tailrace into the lower river about 7.2 km below the diversion dam which is 4.0 km from salt water (Fig. 1).

This project impacted in several ways on the two distinct stocks in the river. The summer chinooks, which move into the river in early summer and spawn in the upper reaches of the stream, were affected by several direct damaging factors. The fall chinooks, which move into the river in early autumn and spawn in the lower reaches of the stream, were affected more by gradual indirect damage. As a result both of these stocks are now at less than ten percent of their pre-development level. Restoration of these chinook stocks to their former level is the primary aim of the biological program. The secondary aim is to enhance these stocks as well as the coho and steelhead stocks to a level beyond the pre-construction level.

The following report includes, documentation of selected physical parameters in the Puntledge River system; details of the activities carried out to enhance the production of salmonid from brood years 1972 to 1977;

biological hatchery program for 1978; assessment of the effectiveness of enhancement activities and accomodation for future work.

The report is divided into four sections, a summer chinook section, a fall chinook section, a coho section, and a steelhead section.

SUMMER CHINOOK

Summer chinook originally spawned in the section of river between the diversion dam and Comox Lake. Adults enter the river on their spawning migration in June, July and August and spawn in October. The juvenile downstream migration occurs during March to July.

Early escapement records place the summer chinook population in the river at a level of about 3,000 spawners prior to 1955, however in recent years their numbers have declined to a level of approximately 400 spawners (Table 5).

The fisheries problems associated with the decline are the following:

1. A reduction in flow between the diversion dam and powerhouse which increased the hazard to migrating adult salmon at Stotan and Nib Falls.
2. Attraction to the increased flow at the powerhouse tailrace which delayed adult migration and caused injury to fish in draft tubes.
3. Modification of the intake works and an increase in diversion flow resulting in a major portion of downstream migrant chinook juvenile passing through the turbines.
4. Loss of upriver rearing area since channel construction.

Measures taken to reduce the adult injury problem and aimed at resolving fisheries problems at the Puntledge River from 1954 to 1972 are presented by Marshall (1973). In an attempt to mitigate the problem of turbine mortality to juveniles, an artificial spawning channel was constructed by Hydro in 1965 at a location adjacent to the diversion dam (Fig. 1). The channel was designed to replace the natural spawning areas above the diversion dam and enable downstream migrant juvenile chinook to enter the river below the intake works. This terminated efforts aimed at salvage of juveniles at the intake works (1956-1964) and night time closures of the powerhouse (1965) during the juvenile migration period (Lister, 1968). However due to poor survival rates in the channel, supplementary hatchery propagation of summer chinook salmon was initiated in 1972 utilizing temporary incubation facilities installed in the Old Canadian Colleries Powerhouse and in two 75 foot concrete Burrows type rearing ponds constructed at the channel site (Fig. 1). From this date (1972) therefore, the production of summer chinooks has resulted from 3 sources; natural spawning in the river, natural spawning in the channel and artificial propagation in the hatchery.

This section of the report will deal only with the summer chinook stocks in the Puntledge River over the brood years 1972-77, and will provide :

1. a brief documentation of natural spawning and fry production in the river,
2. a complete description of the spawning channel programs, and
3. a complete documentation of the hatchery program.

A. RIVER PRODUCTION

During the past five brood years (1972-1976) visual observation has shown that the number of spawners in the river below the diversion has remained relatively constant at around 80 adults (Table 4). The following is a year by year account of spawning and distribution of summer chinooks in the Puntledge River below the diversion dam.

Brood 1973 - An estimated 53 (16 females) spawned in the river a few hundred yards below the channel and an estimated 12 (2 females) spawned in a side channel in the vicinity of the Crown Zellerbach logging bridge (Fig. 1).

Brood 1974 - It was estimated that 51 (21 females) spawned in the river a few hundred yards below the channel and 24 (11 females) spawned in the vicinity of the lower pool.

Brood 1975 - It was estimated that 60 (18 females) spawned in the river a few hundred yards below the channel and 16 (6 females) spawned in the vicinity of the lower pool.

Brood 1976 - It was estimated that 90 fish (30 females) spawned at four locations in the river. River spawning extended much further downstream than in past years. This may be attributable to the presence of predators in the channel.

Estimates of fry production from the river are contained in Table 5. These estimates are based on the number of females observed spawning in the river x average fecundity x estimated survival rate. For the past five years, 10,000 summer chinook fry are estimated to have been produced in the lower section of the river downstream of the diversion dam.

B. SPAWNING CHANNEL PRODUCTION

Introduction

The spawning channel began operation in June 1965. The entire cost of construction, operation and maintenance has been borne by the Hydro and Power Authority. The Department of Fisheries has undertaken a continuing study, including the measurement of adult escapement and resultant fry production, to assess the effectiveness of the channel. Previous spawning channel reports include Lister (1968) and Marshall (1973).

Description of the channel

The spawning channel is 254 m long and has a gravel bottom width of 7.5 m. The spawning gravel consists of 2.5 cm to 15 cm diameter material laid to a depth of 0.7 m. The total spawning area, 1,905 square meters is considered sufficient to accomodate a population of approximately 1,000 (400 females) summer chinook salmon. The bottom slope of 1.3 m per thousand is designed to provide an average water velocity of 0.76 m per second at an operating depth of 0.42 m. Four 2.5 meter deep holding pools constructed of timber cribbing are distributed throughout its length (Fig. 2).

Adult summer chinook are prevented from gaining access to the former natural spawning areas by a barrier rack on the diversion dam and are thereby directed to the channel via a 23.2 m long fishway, the entrance of which is located at the base of the dam.

The water supply is introduced through a flow diffuser system by two electric pumps capable of discharging approximately 2,800 litres per second in total and a diesel standby pump of (1,000 lps capacity) which comes into operation automatically in the event of power failure. During the adult pre-spawning holding period (June - September) and the spawning period (October) the discharge is maintained at 2,800 lps. Throughout winter incubation and fry emergence flow is reduced to 1,400 lps.

Remedial measures on spawning gravel quality

In the fall of 1973 (between the two basket plant experiments), it was observed that the surface run-off water eroded the banks of the channel and carried fine particles of clay into the spawning channel. It was thought that this might be a major cause of low egg-to-fry survival. As a result, Hydro ditched the high side of the channel and placed a culvert in front of the channel intake to carry surface run-off water approximately 61.0 m downstream from the spawning channel intake pumps. In addition all banks on the project were seeded.

Between July 2-4, 1973, the spawning gravel was cleaned and a new grade line established which provided uniform flow over the length of the channel. This work took place after chinook and trout migration. Early arriving adult summer chinooks were blocked from entering the channel.

In 1975 the spawning gravel was not cleaned. Instead a diffuser fence was installed in pool no. 2 of the channel to prevent adults from spawning in the first section of the channel. This resulted from egg plant experiments conducted in 1972 and 1974 which indicated that survival was higher in the lower sections.

Methods

Adult spawning and egg deposition

Adult summer run chinook were enumerated upon entrance to the channel. In addition the number of spawners in the river and in a side channel in the vicinity of the Crown Zellerbach Logging Bridge were recorded. Periodic swims of the river were also conducted.

Enumeration of spawned and unspawned fish at the channel were carried out by recovery of carcasses. Data on sex, weight, length, injuries, and egg retention were recorded for each fish. In addition the numbers of unspawned females, and the number of summer chinooks taken for hatchery purposes from the channel were recorded. Fecundity was estimated by the following formula: Fecundity = -4,071 + 12.40 x hypural length (mm)

Data on age, weight, length, sex composition, fecundity and mark recoveries of adult summer chinooks is contained in section C of the report dealing with hatchery propagation.

Survival rate - channel basket plants

The purpose of the basket plants were to assess the effectiveness of the gravel cleaning and regrading operation carried out in the spawning channel without waiting for completion of the fry enumeration operations in the spring. Incubation survival at the channel has been very low since 1970 despite repeated efforts to clean the gravel. The basket plants indicated at what stage mortality occurred. Basket plants were carried out for brood 1972 and 1974.

Brood 1972: On October 22, 1972, six baskets, each containing 100 green water hardened summer run chinook eggs were buried in sections 1, 2 and 3 (two baskets per section) of the channel. The baskets were 15 cm cubes constructed of fine mesh galvanized screen painted with rust proof "tremclad" paint.

The baskets were filled with gravel, eggs were added, the lids were stapled shut, and were buried approximately 25 - 30 cm deep in their respective positions in the channel. Each basket location was marked with red plastic surveyor's tape.

On November 20, 1972, the baskets were removed from the channel. The eggs at this stage were all eyed. Survival for each section was calculated.

On November 16, 1972, an additional six baskets, each containing 100 eyed eggs were planted in approximately the same locations as the green egg baskets. On December 18, about the time of hatching, three baskets were removed, one from each section of the channel. The remaining three were removed in February. Survival for each section was calculated.

Brood 1974: A series of 15 baskets of fertilized eggs were planted in three sections of the channel on October 14. Survival was calculated after each basket was filled with gravel; 100 fertilized eggs from two females were added. Lids were stapled closed and each basket was buried 20 to 30 cm deep in sections 1, 2 and 3 (five baskets per section). Eggs for the basket plants were split into two groups. Eggs from the first group were taken to the hatchery, fertilized and then placed in a tray as control group 1. The other group were taken to the channel, and after the basket planting was completed (4 hours later), the remainder was brought to the hatchery site, fertilized, and designated as control group 2.

On November 13, 1974, the first set of baskets were removed from the channel and the survival rates of these eyed eggs were determined. On December 23, 1974, the second set of baskets were removed. The pick was at the alevin stage. The remaining 3 baskets from mid channel were removed at the time the control groups were ponded.

Fry Enumeration

Enumeration traps installed at the lower end of the fishway draining the channel, were fished continually until the end of fry migration. The enumeration gear is made up of three 15 cm wide screened inclined plane traps with aluminum live boxes bottled to the lower end. The upstream end of each of the traps were fastened to a stop log while the lower end was suspended by a cable, attached to a 1/4 ton hand operated winch.

Trapping efficiency was determined by releasing marked fry (Bismark brown) above the enumeration gear in the evening, then determining the percentage recaught the following morning.

Periodic weight estimates of fry (fish per lb) were conducted on 50 fry during downstream migration from the spawning channel.

For brood years 1974, 1975 and 1976, after removal of the traps the channel was drained and the remaining smolts in the channel enumerated and forced out of the channel.

Results

Adult spawning and egg deposition

From 1972 to 1976 the number of spawners utilizing the spawning channel has decreased significantly from a high of 255 in 1972 to a low of 16 in 1976 (Table 4). Brood 1977 spawners were not allowed access to spawn in the channel.

Excluding the mortality resulting from predation, adult pre-spawning mortality in the channel has averaged approximately 18 percent from 1972 to 1976. In 1976, extensive predation by bears resulted in a 65 percent pre-spawning mortality (Table 4).

Potential egg deposition has dropped from a high of 0.5 million eggs in 1972 to approximately 15,000 eggs in 1976 (Table 6).

Survival rate

Fry enumeration : percent egg-to-fry survival was extremely low from Broods 1972 to 1974. However in 1975 the highest egg-to-fry survival rate to date at the channel occurred at 64.8 percent (Table 3).

Basket plants : for Brood 1972 and 1974 basket plants show that mortality occurred mainly in the post-eyed stage before hatch (Tables 1, 2). Mortality rates were higher along the left bank than along the right bank (81 percent vs 47 percent) of the spawning channel (Tables 1, 2). Mortality was greatest in the upper section of the channel (section 3) and lowest in the bottom section of the channel (Section 1) (Tables 1, 2).

Baskets removed from sections 2 and 3 of the channel were heavily ladden with clay silt, while the silt load in the baskets removed from section 1 were considerably lighter. In addition, observations indicate that the soil structure in the area in which the channel runs through is made up mainly of clay, with the result that heavy rain and snow run-off continually wash silt into the channel.

Fry production

Fry production from the channel was extremely low in broods 1974 and 1976 (Table 6). However, fry production in broods 1975 and 1972 were moderately high at 55,000 and 67,000 respectively (Table 6).

32,548 Brood 1972 fry were trapped in the channel for hatchery rearing and release at a latter date.

In Brood years 1974 and 1975, after removal of the traps, the channel was drained and an additional 1,000 and 500 pre-smolts respectively were forced from the channel.

Fry emigration pattern

Medium date for fry migration from the channel has varied little from the period 1971 - 1975 (Table 7). However, medium date of emigration for Brood 1976 fry was Febuary 15, the earliest recorded date (Table 7). The majority of juvenile chinook fry migrant from the spawning channel as newly emerged fry during March, April and May (Fig 3). The emigration rate then remains low until late May and June when a second group of migrants, exceeding the first in size begins to leave the channel. The emigration of these fingerlings, about 5 percent of the total, may last until mid July.

There appears to be a correlation between temperature and time of emigration (Table 7). During the first years of operation of the channel, Brood 1965, 1966 and 1967 (Lister, 1968), and for Brood 1976, it appears that warm temperatures during incubation and in February and early March resulted in an earlier emigration of fry from the channel. In later years, (Broods 1970 - 1975), as covered in this report, temperatures have not been as warm during February and March. As a consequence, emigration of fry from the channel is occurring later, approximately 2 weeks later than earlier broods 1965, 1966, and 1967. ATU to median date show that fry are emigrating from the channel at a similar ATU, about 2,000 (Table 7).

Size of fry at emigration

Size of fry at emigration appears to be around 1,120 fish per lb (Fig. 4). There appears to be little difference in size of fry at emigration over brood years 1972 to 1976.

In addition to the above emigration, there still continues a 90-120 day emigration of chinook fry at approximately 110 fish / lb. during June (Fig. 4). This component represents approximately 5 percent of the total emigration.

Discussion

Spawning and egg deposition

During the period 1972 to 1976 the Puntledge River spawning channel has accommodated fewer and fewer spawners (Table 4). The reasons being due to poor production of the channel and increased adults taken for hatchery purposes.

The male to female spawning ratio has increased in the channel mainly due to the taking of more females than males for hatchery purposes.

Adult summer chinook prespawning mortality at the channel is a continuing problem, although less serious than in the 1960's (prior to remedial work at Stotan Falls and diversion dam, and to the implementation of moderate and stable flows in the falls section of the river during the adult migration period.)

On the basis of observations of fish passage at Nib Falls in 1973, it appears that this is the remaining serious migration hazard on the Puntledge River, although the powerhouse tailrace and diversion dam trush racks are still suspect. In regard to the latter, during periodic inspections some fish were observed rushing the tailrace flow, possibly striking the grating over the draft tube.

The major portion of mortality of adult summer chinooks at the spawning channel results from stress, fatique, and head and body injuries resulting from adult migration.

Other forms of prespawning mortality include heavy predation by bears at the spawning channel, which occurred for the 1976 brood, and possible poaching of adult chinooks.

Survival rate and spawning gravel quality

Based on the results of the basket plants and observations made at the spawning channel, it appears that the extremely low survival rate from 1972 to 1976 is most likely due to excessive siltation of the gravel, poor channel grade, and decreasing percolation of water through the gravel. Attempts at increasing the survival rate by gravel cleaning, regrading of the spawning channel, ditching the high side of channel, culverting, and seeding of the spawning channel banks did little to improve survival. In 1975 egg-to-fry survival of 65 percent approximated the level expected in an artificial spawning bed for chinook salmon. However this came about from closing off the upper sections of the spawning channel to summer chinook adults.

Fry emigration

Each year over 95 percent of the fry emigration consisted of emergent fry, approximately 1,120 fish/lb, migrating during March, April, and May. A second component of reared fingerlings, averaging 110 fish/lb emigrate from the channel during late June and early July.

Fry emigration patterns indicate that fry from broods 1972-1975 are emigrating slightly later in the year (2 weeks) than Brood 1976 and fry reported by Lister (1968)for broods 1965-1967. It is believed that this is a result of cooler water temperatures experienced during incubation and at time of emigration during February and March. Puntledge channel chinook emigrate considerably earlier than Cowichan chinook whose peak emigration is the first week in May. (Armstrong and Argue, 1977)

General

The overall performance of the spawning channel since its construction in 1965 has been poor. Although the spawning channel may be credited with maintaining the valuable summer chinook population in the Puntledge River, it has done little to enhance the species. In addition, fry survival rates as a result of excess siltation have been extremely low and methods to reduce siltation have not met with great success. Because of such poor performance by the channel and the need to enhance the extremely low population of the valuable species, more and more emphasis has been placed on hatchery propagation. Therefore, it is planned for the summer of 1977 that the top section of spawning channel be removed and in its place an adult holding pool be built. The two bottom sections of the spawning channel will still be available for natural spawning.

C. HATCHERY PRODUCTION

Introduction

Hatchery propagation of juvenile summer chinook began in 1972 utilizing temporary incubation facilities installed in the Old Canadian Colleries Powerhouse and two 23 meter concrete "burrows"-type rearing ponds constructed at the channel site (Fig. 2). The cost of the facilities was undertaken on a cost sharing basis with B.C. Hydro (Marshall, 1973).

The water supply to the "Burrows" ponds is drawn from the channel by two electric pumps, each servicing a separate pond. An emergency gravity system maintains flow in the event of a mechanical or electrical failure. Water enters the ponds under pressure through submerged nozzles or jet headers and drains through screened openings in the floor of the ponds. A feature of the "Burrows" ponds is the circulating flow. This results in a continuous turnover of water and a self-cleaning action. The discharge from the ponds enters an outlet sump through a standpipe which can be adjusted to regulate pond depth. The water then drains into the Puntledge River below the diversion dam (Marshall, 1973).

Methods

Adult trapping

Since the summer chinooks that utilize the spawning channel enter it in June, July and August, and do not spawn until October, it was a simple matter to gillnet them while they were holding in the channel. This was accomplished using a small mesh gillnet which allowed the chinook to tangle and not gill.

From the gillnets the summer chinook were transferred by tank truck (130 gal.) to the "Burrows" pond. Males and females were placed in separate pens where they were held until full maturity.

Broods 1975 and 1976: After the first fish were observed digging in the channel, flow was reduced to 700 lps and the adult chinook hatchery stock were beach-seined from the channel holding pools.

Holding and sorting

One of the two "Burrows" ponds located at the channel site was utilized for adult holding. The pond was converted into two raceways by extending the center wall to the ends of the pond. This was done with heavy planks or stop logs placed on edge in stop log grooves located for this purpose. Maximum inflow was provided by utilizing both the pumping and gravity flow systems. Outflow was directed over the weir at the end of each raceway rather than through the floor drains.

Each of the raceways were divided into three pens by means of plastic coated wire-mesh panels. Females were placed into the upper section, males in the lower section, leaving the middle section vacant. The middle section was later used for separating ripe and green females. Fall run chinook utilized one raceway, and summer run chinook the other.

The area of the ponds utilized for pens were covered with heavy gauge 10 cm mesh nets to prevent adults from jumping out of the pens. A 1.2 m by 2.4 m sheet of plywood was floated on the water in the female pens to provide cover for the fish.

At the start of ponding adults were continually jumping. To prevent this and possible injuries, lawn sprinklers were operated continuously over the ponds. This had a definite calming effect on the adults.

Males and females were held and sorted separately upon initial ponding in the adult holding ponds. Summer chinook were checked for ripeness on a once weekly basis and as they started to mature they were checked more frequently. The summer adults were not drugged when checked for ripeness.

All summer and fall run chinook captured for egg take were treated with a ten percent malachite green solution before ponding (Knittel, 1972). The solution was applied with a paint brush to the head and body regions, which were susceptible to fungal infection as a result of injury. This procedure was repeated after each sort for maturity.

Spawning and fertilization

The method of selecting females for spawning was to apply pressure to the ovary. Females were judged mature by their degree of firmness and whether eggs spurted out the urogenital pore upon applying pressure to the ovary. This duty was delegated to the most experienced member of the hatchery.

For the males, hold over time, multiple use, and capture throughout the spawning period allowed ample milt for fertilization of the eggs. Killing was accomplished with a sharp blow to the head with a club. Adult females were then bled by severing the isthmus and hanging the fish head down. Females were then washed and dampened dry. Mature males were anaesthitized prior to stripping.

In a shaded area, females were stripped by abdominal incision, one at a time, and eggs were allowed to free fall into a 2.5 liter plastic bucket. Eggs were fertilized with milt after egg counts and fecundity were established by weight. Sperm was added to the bucket after the eggs were counted. If enough ripe males were available, three males were used to fertilize the eggs of one female. After fertilization, the eggs were carefully washed, the buckets sealed, then placed in the river to water harden before transfer to the hatchery at the lower site. Eggs were counted by volume, then placed into "Heath" trays to incubate.

Since brood 1974 the dry fertilization method has been used, whereby eggs and sperm were placed in seperate buckets and transferred to the hatchery site (Armstrong, 1973). At the hatchery site the sexual products were mixed and placed by volume into "Heath" trays for washing and water hardening.

Adult sampling

All adults were sexed, weighed and lengthed (post orbital hypural length). In addition, adults were checked for tags, and scales were taken for age determination. As a result of scale reabsorbtion due to early entry and difficult migration, scales were not readable to any degree of accuracy. Age analysis were made using lengths, but these were judged unreliable, particularly in recent years when extended reared adults returned shorter in length than the average fish a year younger.

Incubation

Eggs taken from females at the channel were incubated in a small hatchery facility located in the Old Canadian Colleries Powerhouse building (Fig 1).

The incubation unit in the building consists of five 16-tray heath cabinets (an additional cabinet was added since 1972) with an overhead flow distribution box. The water supply is connected to the penstock. The water is strained through duplex filters and then enters the distribution box via a dual plumbing system. Flow to the individual cabinets is set at 3 gallons per minute and is regulated by metering boxes located above each cabinet.

Eggs were treated weekly with malachite green using the "California flush" method. The treatment was discontinued once the eggs had hatched.

Dead eggs were removed using a rubber suction glass tube commencing at the eyed stage. No deliberate shocking took place, it was felt that counting and dead egg removal was of a sufficient enough shock to kill blank eggs (Armstrong, 1973). Mortality was recorded for both the eyed and eyed to hatch stages. It was determined by subtracting dead eggs from the initial egg-take count.

Ponding

Prior to transfer from the incubation trays to the pond, fry subsamples were lot weighed and counted in order to determine the number of fish per pound. The wet weight of the fry ponded were multiplied by the number of fry per pound in order to obtain the total number of fry ponded. Fry were then transported in a 130 gallon capacity aluminium fry transport tank. Water in the tank was supplied with oxygen using a cylinder, regulator and airstones.

Fry were normally ponded in a small pen within the main "Burrows" pond, and placed on a low rate of water flow while being started on O.M.P. mash. The fry from 1974 Brood however were initially ponded in the powerhouse prior to transfer to the "Burrows" pond. Some of the 1976 brood (9,514 fry) were ponded initially in a circular tub (3m x 1.2m) at the powerhouse site. These summer run chinook fry were the last eggs taken and were ponded approximately one month later than the summer chinooks initially ponded in the "burrows" pond.

Rearing

One standard "Burrows" pond, 22.86 m long, 6.09 m wide and 1.0 m deep with an inflow of 600 gals./min. was used for all rearing after Oct. 20, 1972.

However, in the spring of 1972, before the ponds were constructed, a total of 32,990 fry of the 1971 brood fry emigrating from the spawning channel were trapped and placed into a specially constructed rearing pen located in the steelhead bypass channel.

After a total of 19,831 normal smolts were released in July 1972, it was decided to rear the remaining chinook fingerlings for one more year. This experiment was conducted in order to determine if the smolt-to-adult survival rate could be increased substantially by rearing to a larger size before release in contrast to the usual method of releasing chinook fry as 90-120 day old smolts. Juvenile chinooks that are reared for a full year before release have been termed "super" smolts.

On October 20, 1972, a total of 7,335 chinook fingerlings were transferred from the steelhead by pass to the newly constructed "Burrow's" rearing ponds.

The brood 1973 chinooks were held over one full year for release as "super" smolts in the summer of 1975.

Loading rates were determined by dividing the total estimated weight of fish present (mean weight per fish x total number of fish) by water flow. Loading rates were calculated for each weight length sample.

Feeding

Due to operational changes and initial startup of the hatchery, feeding was subject to change. When first ponded, the summer run chinook fry were started on a diet of O.M.P. mash (Hublou, 1963). Length of mash feeding varied each year depending on the ponding period length. Daily ration, pellet size, and feeding frequency were based on the number of fish per pound and water temperature (Oregon Moist Feeding Chart).

In the first year of hatchery operation (1972), from the start of the rearing program until April 23, all groups of chinook fry were fed only during the normal working day of 0800 - 1630 hrs.. After April 23, when an additional man was added to the staff, the working day was adjusted to cover the period from 0700 - 1730 hrs.. 1972 Brood summer run chinooks were generally fed twice hourly, while the super smolts were fed once daily until March 26 when they were rescheduled to three feedings per day.

Automatic feeders were installed on July 8, 1974, since then chinook fry have been fed throughout the daylight hours.

1976 brood pinheads salvaged from the "burrows" pond and transferred to a tub for rearing, were fed a special diet consisting of beef liver, plankton, and O.M.P..

Food conversions per time period were tabulated as the wet weight of food distributed divided by the increase in fish biomass.

Growth rate

Growth rate in length and weight were determined using the growth equation:

$$b = \frac{\ln Y - \ln a \times 100}{t_2 - t_1}$$

where b = growth rate
Y = the final length or weight
a = the initial length or weight
$t_2 - t_1$ = the rearing period

In addition, a sample of 50 fry were weighed and lengthed on a biweekly basis. Condition Factors were determined at each sampling period using the following equation (Klontz, unpubl.)

$$K = \frac{W}{L^3}$$

where W = weight of an individual fish in pounds
L = total length of the fish in inches

Mortality

Mortality of the fry were recorded daily from each pond. No allowances were made for recording unaccountable mortality which includes drain loss, predation, and possible cannibalism.

On April 17, a substantial number of brood 1972 summer run chinook fry were found in the drain end of the pond. It was found that fry were escaping under and around the screens and through the gaps in the stop logs where gaskets had blown out. Attempts were made to stop the fish loss by placing five cm square foam rubber lining under the screen and replacing the gaskets on the stop logs. There was some difficulty in keeping the foam rubber in place. To overcome this problem, a flap of carpet underlay was glued to the bottom of the screens. No noticeable fry losses occurred after this treatment.

Pond inventories were estimated initially by the weight of fish ponded with accountable mortality being subtracted over time. No allowance were made for recording unaccountable losses into pond inventories.

Pond cleaning

The steelhead bypass pond where the 1972 summer chinooks were first reared were kept clean by weekly sweepings of the bottom and screens using a heavy bristled broom.

The "burrows" ponds, which are partially self-cleaning, were cleaned once weekly using a swimming pool vacuum attached to a 5 H.P. Briggs and Straton pump. This inexpensive swimming pool vacuum did not last through the rearing period but considering how useful this equipment was, it was recommended that a more durable model be purchased. The sides of the ponds were scrubbed using a long-handled broom.

During winter rearing of "super" smolts, the ponds were not cleaned, but starting in late winter a heavy build-up of algae on the sides and bottom of the ponds occurred. The algae was removed by sweeping vigourously with a heavy bristled brush. As water temperatures started to rise, the algae problem diminished and the ponds became virtually self-cleaning.

Marking

Marking normally consisted of adipose fin-clipping and binary wire coding a proportion of summer chinook fingerlings (Jefferts, Bergman, Fiscus, 1963). The following brood changes occurred :

1971 Brood : In the first year of hatchery operation, the only method employed was feeding tetracycline impregnated food prior to release. This tetracycline series of antibiotics localizes in areas of bone proliferation and under ultraviolet light is identified as a flourescent yellow line. Weber and Ridgeway (1967) give details of this marking technique.

In addition to the tetracycline marks, the 1971 brood "super" smolts were marked in April 1973 with a colour coded wire and adipose clip. At the time of marking "crinkle-back" chinooks (501) were separated from the marked smolts and released directly into the river.

1973 Brood : "Super" smolts from this brood were marked in February 1975 when water temperatures were cooler. A first attempt at marking was made on July 1974, but was abandoned due to high mortality.

1975 Brood : Marked fish were not randomly selected from the population, but were graded according to size. This was necessary, because a large proportion of the fish were of too small a size to marked, and it was the only time that tagging machines were available.

Release

To estimate the total number of fish to be released, four 5 lb. samples were taken, counted and separated (marked to unmarked). Then each total was weighed again. Mixed fish (marked and unmarked) were sampled for length and weight. All marked fish (missing adipose fins) were run through a detector to determine the percentage of pin dropout. By knowing the total number of marked fish, it was possible to estimate the total number of fish released. The summer chinook smolts were released at the upper site below the diversion dam.

Release changes were made for the 1975 Brood : Samples were separated by weight into marked and unmarked groups which were then counted and weighed. All marked fish in this sample were run through a detector to determine the percent tag loss.

Technical support

The Nanaimo Biological Station provided a disease diagnostic service. Periodic sample of summer chinook adults and juveniles were taken and tested for bacterial, viral, and parasitic diseases.

Results

Adult escapement

Summer run chinooks have declined significantly during the past 13 years. Escapements from 1972 to 1976 indicate that the summer run chinook are holding their own at a level of approximately 300 spawners (range 273-425) (Table 8).

Adult sampling

Based on returns to the channel only, sex composition of summer run chinook adults entering the Puntledge River is approximately 2 : 1 male/ female (Table 9).

Although age determinations based on scale samples and length compositions are not always accurate, it is indicated that the majority of females tend to return as 4 year olds, approximately 25 percent as 3 year olds, with a small percentage of five year olds. Males tend to return as 3 year olds with approximately 25 percent returning as four year olds, and a small percentage of two and five year olds returning (Table 10).

Length of males appears relatively constant over the past 12 years averaging 583 mm (Table 11). Females are longer than the males averaging 690 mm (Table 11). Based on earlier length records it appears that the overall length of both males and females was greater prior to construction of the new generating facilities in 1955 (Table 11). However, earlier samples excluded jack lengths (Table 11).

Adults returning from the extended freshwater rearing program ("super" smolts) were significantly shorter than the smolts of the same year class that were reared for 90-120 days.

Data on weight of summer run chinook adults is limited and only available for broods 1972 and 1973 (Table 12). Females averaged 5.40 kg compared to 4.0 kg for males. Comparing present weight data with earlier data (1955-1956), it appears the average weight of males and females has significantly decreased from 7.9 kg to 4.6 kg (Table 12).

Adult holding mortality

Female holding mortality of adult summer chinooks were extremely high in 1972 and 1974 at 33 and 50 percent respectively (Table 13), while negligible in other years.

Fungus infection resulting from injuries to the body as a result of migrational hazards, netting and handling, responded well to malachite green treatment. Malachite treatments of fungused adults prevented the spread of the fungus and reduced adult mortality due to infection. It was also noted that if the malachite green was applied before the fungus had spread, only one application was needed. Within a week of treatment, the mycelial mat almost entirely disappeared in the majority of cases, leaving what looked like a grey-white scab (Knittel, 1972).

Date of maturity (egg take) has varied little from 1972-1976, ranging from September 29 to October 24 (Table 13). The largest egg take brood was 1975 with over 300,000 eggs collected (Table 14). The number of eggs/tray has averaged 5,000 for broods 1972 to 1976 (range 3,500 to 6,200 per tray) (Table 14).

Fecundity and egg retention

Average fecundity for six years of data ranging from 1966 to 1976 remains relatively unchanged at approximately 4,564 (Table 15). Egg retention values were extremely high in 1972 and 1973 at 20 and 30 percent respectively. However in latter years its average was about 10 percent. Correlation of fecundity on length is significant with an R of 0.79 (Fig. 5).

Incubation mortality

Mortality to ponding has been reduced from an average of 20 percent to approximately 10 percent for the last two brood years (1975 and 1976) (Table 14). The greater part of the mortality occurred in the fertilization to eyed stage. For Broods 1973 and 1974, one and two females respectively were stripped while still in a "green" state.

Figures 6 and 7 graph incubation mortality of chinook eggs against the number of eggs fertilized per day (Fig. 6), and the temperature of egg-take (Fig. 7). Neither graph shows a significant correlation at the 0.05 level of significance.

Ponding

Ponding has taken place following an average incubation period of 132 days (range 120 to 147 days) (Table 16).

The period of ponding of summer chinook is generally protracted. The longest period over which this has taken place is 53 days in 1974, the shortest 13 days in 1973 (Table 16). The mean ponding date has been earlier year after year with Jan. 15, 1977 being the earliest date recorded (Table 16).

Mean ATU°C from fertilization to ponding has averaged 859 (range 734 to 991) for broods 1972 through 1976 (Table 16).

The mean temperature at ponding for broods 1972 through 1976 has been 5.7°C (range 4.2 to 9.0).

Brood 1972 was the last year that chinook fry trapped from the channel were reared at the Puntledge.

Size at ponding

Brood 1976 fry were ponded at the largest size, while Brood 1974 fry were ponded at the smaller size. Average size at ponding for Broods 1972 to 1976 has been 1,100 fish/lb (Table 16).

Figure 8 relates adult female size on resulting fry size. However, the correlation is not significant at the 0.05 level, possibly due to small size of the sample.

Feeding and growth

Broods 1973, 1974 and 1976 display extremely high food conversion rates (Table 17). These high food conversion rates are likely due to over estimation of the number of fry in the pond in light of heavy mortality in the ponds. The remaining brood years display normal food conversion rates (range 1.46 to 1.84). The food conversion rate for the 1971 "super" smolt group is slightly higher than the 1973 super smolt group (Table 17).

Growth rates (%/day) averaged approximately 2.03%/day for Broods 1972 to 1976, 90-120 day chinook smolts (Table 17). A higher growth rate of 2.79 %/day was recorded for the 1971 Brood channel trapped fry that were reared at the hatchery. Growth rates for brood 1976 fry were 1.47 %/day for fingerlings reared in the "burrows" pond and 2.27%/day for fingerlings reared in the tub at the incubation building (Table 17). While growth rates for the two super smolt broods averaged approximately 1.20%/day.

Figures 9 and 10 graph the relationship of length on ATU°C for summer chinook rearing of broods 1971 through 1976. All correlations are significant at the 0.01 level. The slope for fry trapped in the spawning channel and pond reared is lower than the slope of hatchery incubated fry reared in ponds (Fig. 9), thus indicating that length / ATU°C in "burrows" ponds is greater for spawning channel trapped fry than for hatchery incubated fry. In addition, figure 10 shows a greater slope for hatchery fry incubated in Heath trays and reared in "burrows" ponds than hatchery fry incubated in heath trays and reared in a circular tub, thus indicating that length / ATU°C is greater for tub rearing than for pond rearing.

Figure 11 graphs length on ATU°C for the 1973 super smolts. Length / ATU°C is greatest during the first 90 days of rearing.

Condition factor averages about 2.4 at ponding and approximately 4.2 at release (120 days) (Fig. 120

Mean fingerling size at release for Broods 1972 through 1976 were 79 fish/lb (range : 49-106 fish/lb) (Table 17). Brood 1971 and brood 1973 "super" smolts were released at 7 and 4.4 fish/lb respectively.

Length of rearing and release

Mean length of rearing has been relatively constant from 1972 to 1976 for the summer chinook fry (range : 120-156 days) (Table 18). Brood 1973 "super" smolts were reared 447 days, while brood 1971 "super" smolts were reared 401 days.

Date of release for 90-120 summer chinook fingerlings has been relatively constant (range June 20 to June 26), while for super smolt groups (range May 17 to May 20) (Table 18). Only for broods 1975 and 1976 have releases been greater than 100,000 (Table 19).

Mortality

Mortality for reared summer chinook fry has been extremely high, averaging 45-50 percent (Table 19). Peak mortality years were broods 1973, 1974, and 1976; lower mortality brood years were 1972 and 1975 (Table 19).

Heavy mortality for the 1971 brood super-smolt group occurred as a result of crinkleback desease, which resulted from a vitamin C deficient diet. On the other hand, once past the 90-120 rearing period, mortality for 1973 brood "super" smolt group were extremely small (10 percent) (Table 19).

The heavy mortality recorded for broods 1972 through 1976 was due to mainly pinheads. These pinheads began dying at 1,400 - 2,000 ATU°C (Fig. 13), and a pond weight of approximately 500-600 fish/lb (Fig. 14).

Increasing flow through the ponds did little to improve the pinhead mortality problem. Treatment of brood 1974 with 1ppm furanace in the food appeared to reduce the mortality to some extent.

Of the 7,000 Brood 1976 pinheads removed from the "burrows" pond, transferred to a circular pond and fed a fortified diet, only 30 percent remained after 45 days (Table 20). However these fry were "healthy" and appeared to be feeding in a normal fashion.

Unaccountable mortality

Unaccountable mortality was high in all years, and is attributed to pinhead mortality, predation, drain loss, and cannibalism (Table 19).

Technical support

In addition to Nanaimo Biological Stations analysis of the pinhead problem (bacterial gill disease preceeded by gill clubbing), they have diagnosed (Tech. Rpt. 707) furuncolosis, bacterial gill disease, and coagulated yolk sac disease in the summer chinook stocks from broods 1972 through 1976.

Adult returns, survival and fishery contribution

CWT returns for brood 1972 show an escapement rate of 0.33 percent and a fishery contribution rate of 1.91 percent (commercial and sport) for a total survival rate of 2.24 percent and a catch/escapement of 5.8/1.0 (Table 21. A.W. Argue unpublished).

Returns for the 1971 brood super-smolt group show an escapement rate of 0.59 percent with a Georgia Strait Head recovery contribution rate of 5.2 percent, for a total escapement of 7.09 percent.* It should be noted that approximately 10 percent of the 1971 super-smolt release group exhibited "crinkleback" disease, and to what degree the remainder of that release were affected remains unknown.

Discussion

Adult escapement

Although 1976 featured a poor brood stock return, it appears that summer run escapements are holding their own at a level of approximately 350 fish. With the hatchery contribution beginning to show in the returns, it is hoped that this level can be enhanced considerably.

*Estimate commercial fishery 1:4 GSHRP.

Adult migration and mortality

The Puntledge River summer run chinook adults still suffer to some degree from 1) fungal infection; 2) fatigue and exhaustion; 3) injury and poaching.

Past work at the falls, tailrace pool and diversion rack, removing possible sources of adult injury and migrational hazards have reduced adult prespawning mortality significantly. However, summer run adults still return to the spawning channel fatigued and exhaused, with varying degrees of fungal infections to the head and body regions. Improved handling of adults over the past few years and malachite treatment of the fungal infections has significantly reduced the adult prespawning mortality of hatchery brood stock (Knittel, 1972).

Although there is no direct evidence to suggest that holding and migration of summer adults in high water temperatures (21°C for 16 days and 12.2°C + for 3 months) have directly contributed to the high prespawning mortality of Puntledge River summer chinooks, high temperatures for prolonged periods may result in stress and fatigue and be a major cause of bacterial infection to adult salmonids. (Coutant, 1970; Holt et al, 1975; Udey et al, 1975).

Sex composition

The variable proportion of females (30 to 50 percent) probably reflects large differences in the relative strength of contributing year classes. Because the majority of females mature at age 4, a low abundance of the age four group in a given year relative to age groups two and three, which include the majority of mature males, can result in an unusually low proportion of females. Two years of sex composition data recorded for Qualicum River (a nearby watershed) fall chinook show a higher percentage of females than males (Sandercock and Minaker, 1975; Paine, Sandercock and Minaker, 1975).

Adult length and weight

Based on earlier length records it appears that the overall length of both males and femalės adults were longer prior to construction of the new generating facilities in 1955. Although correlated to the addition of the new generating facilities, the decrease in size of returning adults reflects an increase during the past 20 years in sports fishing pressure applied to Georgia Strait chinook stocks (A.W. Argue, pers comm.). Past data on size of fry at emigration from the Puntledge River does not indicate that the fry emigrating are significantly different in size in 1955 and 1956, as compared to present fry size emigrating from the channel (Anon, 1955).

Extended reared "super" smolts are returning shorter in length and weight than 90-120 day old chinook of the same year class. Extended rearing therefore is resulting in a reduced growth potential of the stock. It is not known whether this reduced growth potential is directly related to the tendancy of the group to remain within Georgia Strait, the higher survival of the group, or to the loss of one years marine rearing.

Fertilization and incubation

The problem of high adult mortality, egg retention, and incubation mortality of summer run chinook eggs during the past few years has largely been eliminated through; 1) protective controls in the handling and sorting of adults; 2) the addition of the dry fertilization method with water hardening in the trays; and 3) improved hatchery technique and expertise. Mortality during incubation and adult holding does not appear to be related to the high temperatures the adults and eggs are subjected to during adult holding.

Ponding

Due to the absence of temperature control during incubation, protracted ponding of fry is still a continuing problem. One year ponding took place over a period of 53 days.

In addition, according to Wood (1974) temperature at ponding is marginally low for the initiation of chinook feeding.

Growth during rearing

Growth rates (%/day) were greater for fry trapped in the channel and reared in ponds then for hatchery incubated fry reared in ponds. In addition length/ATU°C were greater for channel fry reared in "burrows" ponds than for hatchery fry reared in "burrows" ponds, and greater for hatchery fry reared in circular tubs than for hatchery fry reared in "burrows" ponds. For the "burrows" reared fry graphical analysis appears to indicate that initial growth is slow from first ponding to approximately 45 mm in length. The reason(s) for reduced growth rate of fry reared in the "burrows" pond is likely related to the fact that approximately 40% of the fry develop into pinheads. Pinheads do not show in the fry reared in tubs or in "burrows" ponded channel fry. Once the pinheads die off the growth rate for the "burrows" reared fry is similar to the tub reared fry.

Mortality

Rearing mortality for the summer run chinook fry although lower in 1975 and 1976 is still extremely high in comparison with mortality for other hatchery reared chinooks in British Columbia (MacKinnon, unpublished). Generally the mortality is attributed to the pinhead problem. A number of possible explanations for the high pinhead mortality have been put forward, but to date have produced only increased speculation. The fact that no pinheads show in tub reared fry suggests that the causitive agent is probably a subtle physiological difference in the species that may require a change in culture technique or perhaps early nutritional requirement. However it could just as easily be due to water quality, rearing facility, or a combination of several biological and environmental characteristics.

Some of the following attempts have been made to alleviate the problem, all to no avail:

1) The disease diagnostic section have sampled the same stock for several years, but have not identified any bacteral or viral disease that would cause this problem.

2) Environmental characteristics of the present rearing facilities have not been clearly defined. Of particular interest is the unusually large amount of algae in the spawning channel. Dr. J. Stockner of Pacific Environment Institute, West Vancouver, suggested there could be a subtle synergism between the algae and the fish, however sampling and work to date indicates no harmful algae present and no correlation between algae growth and the pinhead condition.

3) Dr. John Blackburn, Nanaimo Biological Station, has also been briefly involved in observing dissolved oxygen and total gas pressure for one 24 hour period. Nothing unusual was noted.

4) At ponding the summer chinook fry were penned at higher than rearing density in order to ensure that the fry were feeding. The fry showed no abnormal characteristics and appeared to feed in a normal fashion. However during rearing, mortality as a result of pinhead still took place.

Symptoms to date strongly suggest that the summer chinook are suffering from a nutritional problem (nutritional gill disease, anemia, pinheads). Although the fall chinook fry suffer from the pinhead problem to a lesser extent, they appear less affected by a similar diet and nutritional culture techniques, as do a number of summer chinook fry reared in tubs at the lower hatchery site.

One association that has become apparent concerning the summer chinook as well as the fall chinook to some degree is the length of time starter mash is fed in relation to ponding. Without temperature control protracted ponding results; as a consequence mash is fed for a considerable length of time. There is some indication in the data that suggests the longer mash is fed after ponding, the higher the incidence of pinhead mortality. Wood (1974) states that "when 1/32 O.M.P. diet is used to start young chinooks, that both the pinhead condition and gill clubbing are eliminated. Starter mashes, if used at all as the first feed for chinooks, should be fed judiciously. The fry should be started directly on the 1/32 O.M.P. diet; generally there are usually "enough fines" in the 1/32 O.M.P. to accomodate fish as small as 1,500/lb.".

Another possible cause that should not be overlooked as a potential source of the pinhead problem is the high temperatures (16°C +) that adults are exposed to while holding for periods of up to four months prior to spawning.

It is possible that some histopathological or nutritionally deficient condition has developed in the fry as a result of an extensive thermal stress on the adults. Chapman (1970) has shown that smaller eggs and gonads result in sockeye held in high temperatures (17°C +). Additional physiological data indicates that the adults were in better physiological condition when maintained at 10°C, as compared to 17°C. Bouck et al (1975) found that higher temperature were associated with advanced development of secondary sexual characteristics and diminished gonad development.

Although it is generally agreed that chinook salmon can withstand temperatures of up to 21°C for short periods of time without harmful effects, it is conceivable that high water temperatures may affect the nutritional status of the maturing egg which may later result in the pinhead condition in the fry. To date, histological sectioning of samples by Jack McBride (Resource Services, West Vancouver) has revealed no apparent problems. However, he has not yet looked at fry from a latter period of development when losses were greatest.

One final source of the pinhead problem may be genetic in origin. Of the present five hatcheries rearing chinook in British Columbia, only Campbell River fall chinook and Puntledge River summer chinook appear to suffer from excessive pinhead mortality. Some of the possible sources of the pinhead condition at Puntledge mentioned in this report (high adult holding temperatures, protracted ponding, excessive feeding of mash) are not present at Quinsam hatchery. There is no high temperature problem, ponding is controlled through heat unit alteration during incubation and mash is fed for a short period of time. Thus it is possible that the pinhead problem is inherent to these two systems. Although there is no data to back up this theory, it may be possible that these pinheads represent a substock that are not biologically programmed for rearing as 90-120 day chinook. Therefore if as much as 50 percent of the gene pool is lost as a result of pinhead mortality, genetic diversity will clearly be reduced.

Food Conversions

Three 90-120 day chinook brood years displayed high food conversion (broods 1973, 1974 and 1976). These high conversions were likely indicative of inventory problems encountered as a result of high unaccountable and pinhead mortality. Apart from a nutritional vitamin C induced mortality for Brood 1971 "super" smolts, "super" smolts faired well once past the pinhead mortality stage.

Adult escapement to the hatchery and fishery

Total survival of chinook salmon is much less than that of coho and is no doubt related to the smaller size at release and the longer period of ocean rearing. Based on adult recoveries of marked juveniles, escapement of chinook to Puget Sound hatcheries (0.18%) is also much greater than that to the Columbia River (0.08%) (Godfrey, 1969, MS). Godfrey (1971, MS) in his analysis of the Columbia River returns has calculated catch to escapement ratios ranging from 6.4 : 1 to 15.9 : 1 for the 1961-1963 years. Taking into account the number of fish released in these brood years, the average catch to escapement ratio is about 7 : 1. In the absence of any comparable data for the Puget Sound fishery, the same ratio will be assumed. This would then indicate a total survival for Puget Sound hatchery chinooks of about 1.5 percent and for Columbia River chinooks about 0.64 percent. Since both a differential marking mortality and tag loss exist, the adult survival rates given are lower than those for unmarked hatchery fish.

Escapement survival for Puntledge River marked summer chinook based on one complete brood year return is approximately 0.33 percent. Based on a preliminary contribution to the fishery of approximately 1.91 percent, a total survival of approximately 2.24 percent for 90-120 day reared summer chinook is attained. The 1971 supersmolt brood displayed an escapement survival of 0.59 percent. Based on a preliminary contribution to the fishery of approximately 11: 1, a total survival of approximately 7.1 percent is attained.

Puntledge River summer chinooks which were reared one additional year in fresh water and released at about 65 grams (7/lb), produced two times as high a percentage recovery to both the hatchery and fishery as 90-120 day reared summer chinooks. In addition a higher proportion of "super" smolts returned to the Georgia Strait sport fishery than 90-120 day reared chinook. Thus demonstrating a tendency for these super-smolts to remain within Georgia Strait. The super-smolts also returned to the hatchery and the fishery at a smaller size with a higher proportion of three year olds. Although the costs of rearing chinooks as super smolts are considerably high, the fact remains that the rearing of super smolts is an invaluable tool for increasing the summer chinook hatchery stock. However, the benefits attained in rearing one additional year must be weighed against the risks of an additional year of rearing.

Before final conclusions can be drawn from Puntledge River chinook recoveries, each group will have to be examined in relation to tag loss, as unmarked/marked mortality correction factor, estimated Georgia Strait sport fishery sampling rate, and more recent outside Georgia Strait recoveries (Sandy Argue, pers comm.). However, indications suggest that the Catch / Escapement figures for Puntledge River summer chinook are low and current returns indicate survival to the hatchery and fishery of artificially reared 90-120 summer chinook is upwards of 4.0 percent with a Catch / Escapement ratio approaching 5 : 1.

FALL CHINOOK

A) RIVER PRODUCTION

Introduction

Fall chinook spawn in the lower reaches of the Puntledge between the powerhouse and a point approximately 0.5 km below the Condensary Bridge (Fig. 1). Adults enter the river in September and October and spawn in October.

Since construction of the expanded power facilities in 1958, fall chinook escapement has declined to a few hundred spawners (Table 8). The decline is associated with accentuated fall-winter freshets at the Puntledge which commenced in 1958 affecting adult returns in 1961 and later years. The freshets appear to have affected the run through damage to eggs and alevins, and through the eventual loss of much of the spawning gravel.

Since 1972, some of the fall spawners were taken for propagation by hatchery methods. From this date (1972), the production of fall chinooks has resulted from two sources, natural spawning in the river, and artificial propagation in the hatchery.

This section of the report will deal only with the fall chinook stocks in the Puntledge River over the brood years 1972 to 1976, and will provide: a brief documentation of natural spawning and fry production in the river, and a complete documentation of the hatchery program.

Methods

During September to October, weekly float surveys were carried out between the powerhouse and Lewis park in Courtenay to determine the number and spawning distribution of fall-run chinook. In 1975, high flows and muddy water allowed only one float survey in the area. The results of the survey and of the beach seining for hatchery stock were compared with the results of the 1974 return to give an estimated total for the 1974 return.

Results

Fall-run chinook have declined significantly during the past 15 years. Escapements from 1972 to 1976 indicate that the fall-run chinook are holding their own at a level of approximately 300 spawners (range 200-300; Table 8).

Adult spawning in the river has fluctuated over the past five years depending on the adults taken for egg-take (Table 22).

Distribution of fall-run chinooks spawning from 1968 to 1976 is contained in Table 25 (Fig. 15). Heavy spawning areas are 2, 3, 6, 10 and 11. There are trends in the shifting of intensity of use of spawning areas, however it is centered around the above areas. Due to high flows and turbid water in the fall of 1975, only one float survey was made between the powerhouse and Lewis pool in Courtenay. In the fall of 1976, approximately 54 adults were found spawning in a side channel near the proposed lower hatchery site (Fig. 1).

Discussion

The escapement of fall chinook at one time was normally in the 2,000 to 5,000 range, however, within the past 20 years, a drastic decline in abundance to a level of approximately 300 spawners has occurred.

One hypothesis put forward by C.E. Walker (unpublished) for the decline of the fall chinook is that "the spawning grounds have deteriorated, largely through shifting, with the result that good quality gravel area is practically lacking. This condition is reported to be particularly noticeable in the powerhouse region. Measurements of gravel area do not exist, however, the distribution of the spawners is taken as an indication of the presence of good gravel. (This may not be true). At one time the river in the powerhouse region supported large numbers of chinook salmon spawners, in 1968 less than one fifth of the population was observed in the upper four sections of the chinook area. Of this proportion, the high majority of spawners utilized a side channel on the right side of the river. The side channel and occupying population may represent the situation that existed previously in the main stream in the powerhouse area. A complicating problem associated with the decrease of spawning area may be the repeated utilization of the same gravel by various salmon species. In the Puntledge River pink and chum salmon are found spawning in the same localities as the chinook salmon. Additionally, changes in water level may affect survival during incubation and emergence, and, therefore, have had some part in the decline of the fall stock.".

Further to the problem of reduced production of the fall stock, the rearing capabilities of the stream cannot be overlooked. Substantial losses of chinook fry in potholes and pools during March to May, inclusive, have been described by a former fishery officer. Apparently, discharge extremes from the powerhouse resulted in the fry increasing distribution during high flow and being stranded on diminished runoff.

B) HATCHERY PRODUCTION

Introduction

Hatchery propagation of juvenile fall chinook salmon began operation in 1972 utilizing temporary incubation facilities installed in the Old Canadian Colleries Powerhouse and two 23 meter concrete "burrows" type rearing ponds constructed at the channel site (SUMMER CHINOOK:HATCHERY PRODUCTION : Introduction).

Methods

Adult trapping

Initially two methods for trapping the large fall run chinooks were tried, both involved using nets.

Beach seining - the only available spot to beach seine with reasonably good access was directly below the Condensary Bridge. Even this site was only useful during perfect water conditions. Seine sets were made when it was certain chinooks were holding there. Beach seining also involved an excessive amount of handling before chinooks were actually ponded.

Gill netting - the tailrace of the B.C. Hydro power station is a favorite holding pool for adult chinook salmon. It appears that they migrate up to the powerhouse, hold there until they mature, then drop downstream to spawn. Gillnetting was accomplished when the power station was shut down for maintenance.

The gill net was tied to the shore, then pulled across the upper section of the pool and held. An attempt was made, using a rubber boat, to chase any chinooks that had been scared downstream, back into the pool. One end of the gillnet was then released, pulled around into a circle set, trapping the chinooks against the powerhouse wall. Chinooks were then taken from the nets, placed in canvas stretchers, carried to the 133 gallon live tank truck, and transported to the holding ponds at the channel. This was a very successful operation when it could be carried out, but the powerhouse resumed operation after 6 days of downtime and the gill netting was discontinued.

Holding, sorting, spawning and fertilization

After ponding, the fall run adult chinooks were checked and stripped at the same time as the summer run adults, employing the same methods (see SUMMER CHINOOK:HATCHERY PRODUCTION : Methods). The following changes took place:

Brood 1973 - three methods of fertilizing and water hardening were tested.

1) eggs from females stripped were fertilized and water hardened at the stripping site.

2) eggs from females stripped were fertilized at the stripping site, but were water hardened later, upon placing the eggs in the tray.

3) eggs and sperm were transported separately to the hatchery, where the sperm was added to the eggs. The eggs were then placed in the trays to water harden.

Incubation

The methods employed for summer chinooks were also used for fall chinooks (see SUMMER CHINOOK : HATCHERY PRODUCTION : Methods).

Ponding and rearing

See methods summer run chinook. Some of the following rearing changes took place.

Brood 1972 - fry were transferred from the hatchery to a specially constructed pen located in the steelhead bypass fishway. Fry were transferred to the ponds in a 20 gallon plastic garbage can with air being supplied by two battery operated aerators.

Brood 1976 - fry were transferred and ponded from the hatchery to a tub (dim. 3m x 1m) located in the powerhouse (see summer run 1976 for powerhouse rearing details.

Feeding, mortality, pond cleaning

See SUMMER CHINOOK : HATCHERY PRODUCTION : Methods.

Marking

See SUMMER CHINOOK : HATCHERY PRODUCTION : Methods. The following marking changes took place:

1972 Brood : for a six day period ending June 18th, the regular diet of the chinook smolts were substituted with oxytetracycline treated Oregon Moist Pellet. This was the only mark placed on the fall chinook fingerlings.

Release

The fall chinook smolts were released at the powerhouse pool after being transported from the "burrows" ponds by the 130 gal. tank truck.

Technical support

See SUMMER RUN CHINOOK : HATCHERY PRODUCTION : Methods.

Results

Adult sampling

Based on gillnet and seine sampling, the sex composition of fall-run chinook salmon entering the Puntledge River is approximately 3.8 / 1 : female / male. This should not be taken as entirely correct because of the possible sampling selectivity (Table 23).

Based on 2 years of age data, approximately 54 percent of females are four year olds, 38% are five year olds, with the remaining few 3 year olds (Table 23). Approximately 48 percent of the males return as four-year olds, 31 percent as 3 year olds, with the remainder divided up between 2 and 5 year olds (Table 23).

Average length of females from 1972-1976 is 805 mm, males 707 mm.. Males were considerably smaller in 1972 and 1975 (Table 24).

Fish released during seining (Table 26)

In 1973, 121 coho, 40 chum, and 1 pink were caught and released during seining operations.

In 1974, 97 coho, 18 chum, and 1 pink were caught and released.

In 1975, 181 coho, 65 chum, and 10 pink were caught and released.

In 1976, 99 coho, 14 chum and 2 pink were caught and released.

Adult holding mortality, fecundity and egg retention

High adult mortality was experienced in 1972 and again in 1973. In 1973, 5 adults had serious head and body injuries at the time of ponding and did not survive (Table 27).

Date of maturity (egg-take) has varied little from 1972-1976, ranging from Oct. 4 to Oct. 24. Minimal number of eggs were taken for Brood 1972, 1974 and 1976 (Table 28).

Fecundity minus retention has averaged 5,049 during the past five years (Table 28).

Incubation mortality

Mortality to eyeing was extremely high in 1972, 1973 and 1974. High mortality rates in 1972 and 1973 are attributed to the stripping of green fish during egg-take. Mortality to eyeing was extremely low in 1976, while in past years the major portion of mortality has taken place during the eyeing stage (Table 29).

For the 1973 Brood, overall mortality to the hatching stage, excluding the eggs taken from the two dead females (100% mortality) was 31.6 percent. For the group of eggs fertilized and water hardened at the stripping site mortality was 32.4 percent. For the group fertilized at the stripping site but water hardened in the hatchery trays, mortality was 37.6 %. For the group with sperm and eggs fertilized at the hatchery and water hardened in the trays, mortality was 20.5 percent.

Ponding

Ponding of the fall chinook is generally protracted. The latest mean ponding has been March 17 for the 1973 brood, with the earliest Jan. 29 for the 1976 brood. Approximately 2,000 remaining brood 1974 fall run chinook fry were ponded with the summer run chinook fry. The 1975 brood fry were ponded at the largest size, while brood 1972 fry were ponded at the smallest size

(Table 30). Average size of fry at ponding over the past five years has been 927 fish/lb (Table 30). Mean ATU(°C) at ponding has averaged 1,013 during the past five years with ATU being significantly lower in 1972 over all other years (Table 30).

Feeding and growth

Conversion rate for 1972, 1975 and 1976 were similar at about 1.7 : 1. Conversion rate was lowest in 1973 at 1.22 : 1 (Table 30).

Growth rates were highest for 1972 and 1973 broods, with the lowest year being brood 1975 (Table 30). Figures 16 and 17 graph the relationship of ATU(°C) on length for fall chinook reared in the burrows pond (Fig. 16) and fall chinook reared in a tub at the powerhouse (Fig. 17). The slope for ATU on length is lower for tub reared fry than for "burrows" pond reared fry, thus indicating that length/ATU is greater for tub rearing than pond rearing.

Condition factor for fall run chinook averaged approximately 2.9 at ponding and 4.1 at release (120 days) (Fig. 18).

Mean size at release for Broods 1972 through 1975 were 82 fish/lb (range 70-90 fish/lb) (Table 30).

Mortality

Rearing mortality has decreased steadily over the last five years from a high of 50.5 percent in 1972 to about 15 percent in 1976 (Table 31).

1972 Brood chinook fry pond losses in the steelhead bypass were minimal, 238 dead (1.33%). Mortality and unknown pond losses caused by the May 24th flood were high, accounting for 357 (2.02%) and 7,947 (45.1%) fish respectively. Rearing mortality from May 24 until the date of release was 487 (5.24 percent).

Rearing mortality for the 1973 Brood chinook were mainly pinheads. The disease diagnostic service at the Nanaimo Research Board found no virus infection, but there was some evidence myxobacterial gill disease.

Brood 1975 mortality also consisted of pinheads. No evidence of a causitive agent could be found, however bacterial gill disease was shown to be present.

Unaccountable losses are high for all years and are attributed to cannibalism, predation, etc..

Length of rearing and release

Mean length of rearing for the fall-run chinook has ranged from 102 to 119 days for three years of production data (Table 30). Date of release for fall chinook fingerlings has been relatively constant (range June 18-June 27)(Table 31).

Substantial Brood year release have been 1973 and 1975 with releases over 100,000. No release was made for the 1976 Brood as they are to be extended reared to super smolt size (Table 31).

Technical support

Nanaimo Research Board provided a disease diagnostic service. In addition to the Board's analysis of the pinhead problem covered in rearing mortality, they have also diagnosed (Tech. Rpt. 707) furunculosis, bacterial gill disease, and coagulated yolk sac disease. However, no IHN was found.

Adult returns, survival and fishery contribution

CWT returns for brood 1973 show an escapement rate of 0.28 percent and a fishery contribution rate of 4.99 percent (Commercial and sport) for a total survival rate of 5.27 percent and a catch escapement of 17.8/1 (Table 32). This estimate excludes the contribution of age 5 fall chinook to catch and escapement.

Discussion

Adult take

The capture of a sufficient number of adult fall chinook has been a continuing problem since the inception of the hatchery. The only available spot to beach seine with reasonably good access is directly below the Condensary bridge. However this site is only useful during perfect water condition.

Adult mortality

High adult mortalities were experienced in 1972 and again in 1973. In 1973, five adults had serious head and body injuries at the time of ponding and were not expected to live. One possible explanation for the loss of the remaining 15 adults and for the 1972 Brood mortality may be handling stress (Armstrong, 1973). Because of their large size and great strength, sorting of the fish for ripeness was extremely difficult and it was noted that in most instances, some losses occurred a day following sorting.

Fertilization and incubation

The problem of high incubation mortality of fall chinook eggs during the first years of hatchery operation (broods 1972 and 1973) have largely been eliminated through; 1) protractive controls in the handling and sorting of adults, and 2) fertilizing eggs at the hatchery with water hardening eggs in the trays.

Ponding

Due to the absence of temperature control during incubation, protracted ponding of fry is still a continuing problem. In addition, temperature at ponding is marginally low for the initiation of chinook feed according to Wood (1974).

Rearing mortality

Rearing mortality for brood 1975 and 1976 have been normal and comparable with hatchery chinook rearing. Although rearing loss is high for brood

1972 and 1973, the 1972 brood loss is attributed to a high mortality loss resulting from flooding. High mortality for 1973 brood is attributed to the pinhead condition problem.

As with summer chinooks, the symptoms of the pinhead problem are that fish commence feeding in a satisfactory manner but after reaching a size of approximately 400 fish/lb, a portion of them will stop feeding, eventually become pinheads and finally die. Normally we would refer to these fish as pinheads except that they show one symptom not normally shown by the usual pinheads - the gills are clubbed. Such fish are susceptible to bacterial gill disease but the gill clubbing preceeds the bacterium, not vice versa. No infectious agent has been found to be involved and there is no pathology except gill clubbing.

Reasons as to the cause of this problem are contained in summer-run chinook discussion where the problem is of a more serious nature.

Growth rate

Growth rate for reared fall chinook were higher for brood 1972 and 1973. The reason may be related to the selective mortality of the smaller fish (pinheads) of these two broods, thus resulting in an increased growth rate.

Catch/escapement

Brood 1973 was the first year that ad/CWT fall chinook fry were released from the hatchery. Although full returns to the hatchery and to the fishery of brood 1973 are not expected until the fall of 1978 with the return of 5 year old adults, preliminary catch and river escapement data in 1975, 1976, and 1977 is available for this CWT group (A.W. Argue, Table 32). Escapement survival to date for brood 1973 is approximately 0.28 percent. Based on a preliminary contribution to the Fishery of approximately 4.99 percent, a total survival of approximately 5.27 percent for 90 - 120 day reared Fall Chinook is attained at a catch/escapement ratio of 18/1. At such a high C/E ratio a minor increase in exploitation rate on this stock, could conceivably reduce the already low escapements by 50 percent (A.W. Argue, pers. comm).

It is interesting to note that the distribution of catch for Fall chinook is more northerly in comparison to Summer chinook catch. A higher percentage of Fall chinook are caught in Alaska and North and Central Coast than are the Summer chinook. Whereas a higher percentage of Summer chinook are caught in Georgia Strait than are the Fall Chinook.

COHO

HATCHERY AND RIVER PRODUCTION

Introduction

The coho salmon (O. kisutch) of the Puntledge River system contribute significantly to both the commercial and sport fisheries in the Strait of Georgia. These fish use the main river chiefly as a migration route to their spawning grounds located in the tributary streams. Coho salmon begin to enter the river after the middle of September and characteristically congregate in deep pools generally below their spawning tributaries. This holding period varies as does the migrating period. By the time the main body of the run is in the river, which is generally the middle of October, the earliest fish begin to spawn. These fish disperse throughout all available parts of the river with the late fall increase in discharge and the peak of spawning occurs shortly after this. The main bulk of the run to the Puntledge spawn throughout Tsolum River and Morrison Creek. Those that spawn in the main stem spread throughout the river from the junction of Morrison Creek to Stotan Falls. Some fish surmount Stotan Falls and in the past fish have been observed above the diversion dam.

Fry begin to emerge in April and disperse throughout the system to fill the available rearing areas. Some of them migrate to sea as fry but most of them spend a year in freshwater and migrate the following spring as smolts. The timing of downstream migration cannot be exact for this species. The main downstream movement occurs in May for both smolts and fry but fry are constantly being displaced downstream throughout the summer.

Based on the observations that some coho surmount Stotan Falls, it was decided that this may be the basis for possible rehabilitation and enhancement of coho stocks in the Puntledge River. Using existing facilities, it was decided that emigrating brood 1976 coho would be trapped from Morrison Creek and reared at the upper site, mainly to determine how the coho would perform under the high summer temperatures of the Puntledge River. If successful, an attempt will be made to trap Brood 1977 adult coho in the Puntledge River for hatchery brood stock.

What follows is a preliminary look at the rearing performance of Morrison Creek trapped coho.

Methods

Juvenile trapping

On February 21, 1977, a fyke net trap was installed in Morrison Creek to capture brood 1976 coho fry for rearing at the upper site of the Puntledge River hatchery. All coho fry trapped were transported to the upper site for rearing.

Ponding and rearing

The juvenile coho were initially ponded in a 1.5 m x 1m tub and later transferred to a section of the "burrows" pond and reared (see SUMMER CHINOOK : HATCHERY PRODUCTION : Methods).

Feeding, mortality, and pond cleaning

- See SUMMER CHINOOK : HATCHERY PRODUCTION : Methods.

Marking

The coho are to be marked (see SUMMER CHINOOK : HATCHERY PRODUCTION : Methods) during the spring of 1978.

Release

The coho will be released at the upper site (see SUMMER CHINOOK : HATCHERY PRODUCTION : Methods) during late May, 1978.

Technical support

- See SUMMER CHINOOK : HATCHERY PRODUCTION : Methods.

Results

Juvenile trapping

A total of 25,615 - 1976 Brood coho fry, at a weight of approximately 1,000 fish/lb were trapped in Morrison Creek (Table 33). The median date of trapping was April 9, 1977 (Table 34).

Feeding and growth

Conversion rate for the first four months of rearing was 1.9 : 1 (Table 35).

Coho attained a size of 149.3 / lb by June 27, 1977, at an ATU (^{o}C) of 1,033 (Table 33).

Mortality

Mortality for coho appeared small during the first few months of rearing. No noticeable incidence of high mortality has since occurred.

Discussion and Summary

Juvenile trapping

A sufficient number of "healthy" juvenile coho were captured from Morrison Creek to determine whether coho rearing will be successful under high summer water temperatures present in the Puntledge River.

Feeding and growth

The wild trapped coho exhibited no problems in commencement of feeding, and displayed an adequate size after four months of rearing. Although at the time of this report the coho had not been exposed to high summer temperatures (21^{o}C +), it appears that the coho will have little problem in acclimating to the Puntledge River Temperature regime. Robertson Creek displays high temperatures during the summer, and aside from going off their feed for a short period, the coho are healthy (K. Peterson, pers.comm.)

It is possible that under high temperatures Puntledge coho may grow too large, which may result in fish-space and feed-cutback problems.

Rearing mortality

Rearing mortality for the first few months of coho rearing appears normal and comparable with other hatchery coho rearing mortality rates.

Summary

Before final conclusions can be drawn concerning the potential for coho rearing at Puntledge River, one complete Brood year rearing must be completed. If the Brood 1976 coho that were trapped survive the high water temperatures present in the Puntledge River during the summer, it is planned that adult coho will be trapped for hatchery stock in the fall of 1977.

STEELHEAD

A) SPAWNING CHANNEL AND RIVER PRODUCTION

Introduction

The Puntledge River system once supported one of the largest steelhead populations on Vancouver Island. However since the advent of the power facilities on the Puntledge River in 1955 the steelhead population has declined dramatically resulting in the closure of the steelhead fishery on Puntledge river.

Although steelhead are largely a provincial responsibility, in recent years the Federal Government, in particular the Puntledge River hatchery has directed an effort aimed at enhancing steelhead in the Puntledge River to historic levels.

Little is known about the Puntledge River steelhead. What follows is the spawning channel production and hatchery production of steelhead during the past three years.

Adult enumeration

Brood 1976 steelhead were the first brood of steelhead monitored by Fisheries staff. 17 adults migrated into the channel between December 4, 1975 and June 14, 1976. A total of twelve 1977 brood steelhead were trapped at the spawning channel (Table 33). Six adults were released upstream of the diversion dam and spawning channel.

Juvenile enumeration

A total of 5,760 brood 1975, 10,260 brood 1976, and 7,583 brood 1977 steelhead fry were estimated to have emigrated out of the channel during the period of downstream migrant trapping. A total of 53 brood 1976 and 99 brood 1977 steelhead smolts were estimated to have emigrated out of the channel during the period of downstream trapping.

All juvenile brood 1977 steelhead fry trapped were held for an additional year of rearing at the hatchery (see STEELHEAD : HATCHERY PRODUCTION).

Median dates for steelhead fry emigration were June 7 for brood 1975 and June 15 for brood 1976 (Fig. 19).

Discussion

With the cooperation of the Provincial Fish and Wildlife Department and under the Federal Salmonid Enhancement Program, the steelhead program at Puntledge River will receive a greater emphasis in the future.

To date there is no published information concerning spawning of Puntledge River steelhead clearly defining the extent of spawning areas used by the stocks within the system. Even less is known about dispersal of young fish from the spawning areas into the river during their period of freshwater residence before first going to sea.

Without much of the information indicated above as lacking, effective management of steelhead stocks will be difficult at best. Therefore there is a strong need to inventory the Puntledge River steelhead stocks.

B) HATCHERY PRODUCTION

Introduction

With the approval of the Provincial Department of Fish and Wildlife, hatchery propagation of juvenile steelhead salmon began in 1977 utilizing temporary incubation facilities installed in the Old Canadian Colleries Powerhouse and fiberglass tubs constructed at the upper spawning channel site.

Methods

Adult trapping and spawning

During the spring of 1977, the Fish and Wildlife Branch with the help of anglers, captured adult steelhead for hatchery stock by angling and seining. Upon capture the adults were transported to the hatchery and placed in a "burrows" pond until they matured.

Spawning, fertilization, and incubation

- see Methods : SUMMER CHINOOK : HATCHERY PRODUCTION

Ponding

Fry were ponded in a 1.8 m diameter fiberglass tub in the powerhouse at the lower site.

Juvenile trapping

All downstream brood 1977 steelhead fry that were trapped from the spawning channel were held for an additional year of rearing in 1.8m diameter tubs located at the upper site. In addition all fry seined from the spawning channel during July 23 - 27 were held for an additional year of rearing in a 1.8 m diameter tub at the upper site.

Feeding, growth and mortality

- see Methods : SUMMER CHINOOK : HATCHERY PRODUCTION

Marking

Marking will be conducted in the spring of 1978. Marking will consist of adipose finclipping and binary wire coding the steelhead fry.

Release and technical support

- see Methods : SUMMER CHINOOK : HATCHERY PRODUCTION

Results

Adult trapping and spawning

During the spring of 1977, 36 male and female brood 1977 adult steelhead were captured for use as hatchery stock. Holding mortality during the egg-take was one female (Table 37).

Incubation

A total of 53,776 eggs were taken from 14 females and incubated in "heath" trays at the powerhouse (Table 37).

Survival from fertilization to ponding was 91.3 percent (Table 37).

Ponding

On June 5 - 12, 1977, 10,092 steelhead fry were ponded in a 1.8 m diameter fiberglass tub in the powerhouse at the lower site.

On June 15, 1977, the water temperature reached 17°C (high in comparison with mean water temperature at Puntledge River during this time, Fig. 21) at which time the alevins and fry in both the "heath trays and tub contacted bacterial gill disease. By June 21, 1977 all steelhead fry in both the "heath" trays and tub were lost (see Technical support).

Juvenile trapping

During downstream migrant trapping at the channel, a total of 1694 brood 1977 steelhead fry were trapped for rearing (Table 39). An additional 1,783 brood 1977 steelhead fry were seined from the channel. In total, 3,477 brood 1977 steelhead fry were ponded together and reared in a 1.8 m diameter tub at the upper site (Table 39).

Feeding, growth, and mortality

Mean weight and length of the brood 1977 steelhead fry are recorded in Figure 20. By October 26, 1977 the steelhead fry reached 30.7 fish/lb.

No significant mortality occurred to the brood 1977 steelhead fry during the first 6 months of rearing.

Length of rearing and release

The brood 1977 steelhead pre-smolts will be released at the upper site below the diversion dam in late May, 1978 after approximately 360 days of rearing.

Technical support

The brood 1977 steelhead that were incubated in the powerhouse were diagnosed by Nanaimo Biological Station personnel as having suffered 100 percent mortality from bacterial gill disease.

Treatment of a portion of the alevins with potassium permanganate 2 ppm (a one hour bath for 3 consecutive days) resulted in 100 percent mortality of the fry within 15 minutes of treatment. A follow-up treatment on another portion of steelhead fry with 0.5 ppm potassium permanganate (one hour bath for 3 consecutive days) resulted in 100 percent mortality. The few remaining alevins were treated with furanace 1 ppm, (one hour bath for 3 consecutive days). These alevins also suffered 100 percent mortality. By June 21, all Brood 1977 steelhead fry incubated in the powerhouse were lost.

It was of the opinion of Mr. G. Hoskins (Resource Services, Nanaimo Biological Station) that the Brood 1977 steelhead fry incubated in "heath" trays at the powerhouse would have died either through handling or treatment.

Discussion

Along with the incorporation of steelhead into the Puntledge River hatchery program goes a need for further research into both the incubational and rearing requirements of steelhead. Although no problems were encountered with the holding and spawning of steelhead adults, problems were encountered with alevins during late incubation and ponding. The 100 percent mortality loss of brood 1977 steelhead alevins incubated in the powerhouse was due to bacterial gill disease. Although there may be many causes of bacterial gill disease (Wood, 1974), it's believed that unusually high water temperatures in the Puntledge River (17°C) during June precipitated the disease. Wood (1970) recommends that incubation temperatures for steelhead not exceed 13°C. Those steelhead fry from the same brood trapped and reared from the channel showed no sign of bacterial gill disease and had little mortality loss. In addition the fry showed an excellent growth performance and it is expected that these fry will meet with the Provincial Fish and Wildlife goal of steelhead released at 8 fish/lb.

Currently, Federal hatcheries in B.C. raise young steelhead as smolts ready to go to sea, at one year of age, even though steelhead normally migrate to sea at two or more years of age. The reason for promoting early growth is simple: the total input of food and care is less, and rearing ponds are used most efficiently when a brood is released each year. There is a need in some areas (especially cold water systems) for research into methods of economically producing fish meeting the size and condition criteria on schedule (Withler, 1972). Indications are that for Puntledge River steelhead it is possible to meet the release size and condition criteria established by the biologists of the Provincial Fish and Wildlife Department.

It appears that the addition of the power facilities on the Puntledge River in 1955 suppressed steelhead production in the system, however without inventories of the number of steelhead present in the watershed over the past years, it is difficult to assess the effects that hydro development has had on the stock. Although hatcheries are not a "cure all" technique to solving declining steelhead escapement. It appears in the case of the Puntledge River system that there may be no other form of compensation. Hopefully, the addition of steelhead to the hatchery program coupled with an effective management program of the natural production will rectify the declining steelhead stock in the Puntledge River, thereby promoting the return of freshwater angling on the Puntledge River.

GENERAL SUMMARY AND RECOMMENDATIONS

The Courtenay - Puntledge - Tsolum River system was at one time perhaps the best fish producing river on Georgia Strait, with the exception of the mammoth Fraser River system, and contributed significantly to the fishing in the northern part of the Gulf of Georgia. Puntledge tyee once supplied part of the Campbell River fishery, a coastal fishery north of Comox and a local tyee fishery in Comox Bay. However since construction of the new power works in 1955 chinook are down to a few hundred spawners annually for each run, and steelhead numbers have declined so low that the Provincial Fish and Wildlife have closed the river.

With hatchery contribution beginning to show in the returns, it is hoped that the level can be enhanced considerably.

Rather than strive to rebuild the run to its former level of abundance, a higher and more stable level may be desirable to fill the needs of the commercial and sports fisheries. In addition to existing facilities, the addition of new facilities at both the upper and lower site (1978-1979) should increase production capacity to approximately 5.0 million chinook smolts, 0.6 million coho smolts, and 75,000 steelhead smolts. With a survival rate equal to the highest migrant fry-adult escapement survival rate obtained to date from the hatchery (0.33%), the hatchery would be expected to produce a return of 17,000 chinook adults which would probably provide an ocean fishery (commercial and recreational) contribution of at least 85,000 adults (Catch/Escapement 5:1). In addition the start-up of a local river fishery could perhaps crop an additional 17,000 x 0.25 percent = 4,250 chinook, leaving an escapement of (17,000-4,250) = 12,750 chinook to the river.

Adding the returns from natural production of summer run chinook to hatchery production along with the addition of coho and steelhead to the program, would adequately meet the needs of an economically important local sport fishery, at least for the foreseeable future.

In order to meet the needs of the above hatchery production and protect the integrity of the stocks spawning in the Puntledge River, the following recommendations must be met:

1) Continued observation on adult migration hazards and further remedial work if necessary.

2) In contrast to the summer chinook run which, with present protective measures is probably secure at its present level of 450 spawners, the fall chinook run appears vulnerable to further setbacks and the loss of one or more brood year classes is a distinct possibility. With the proposed fence to become operational in the fall of 1979, a strong emphasis must be placed on capturing as many fall chinook as possible.

3) It is important to note that we cannot distinguish between late migrating summer-run chinook and early migrating fall-run chinook. Although the two separate hatchery sites on the river will help in preventing hybridization. There does remain a danger of "hybridizing" the two stocks of chinook returning to the Puntledge River. Therefore in order to prevent the loss of the unique qualities of these two races and their separate contributions to the fisheries, it may become necessary to allow any adults arriving at the lower trapping facilities to migrate upstream voluntarily between say mid August and mid September.

4) Considerable problems still exist with holding early summer-run chinook, especially under the high water temperature extremes during summer. Continued monitoring of adults during holding, malachite treating, and the conversion of the spawning channel into a deep adult holding channel should aid in alleviating this problem.

5) Problems with steelhead incubation were first encountered during 1977. It may become necessary to cool incubation water in order to prevent high mortality of steelhead alevins resulting from high temperature induced bacterial gill disease. In addition further research dealing with the incubational needs of steelhead is required.

6) High mortality resulting from pinheads in the summer-run and to some extent the fall-run chinook is probably the biggest problem the hatchery faces. On going research aimed at solving the pinhead problem through diet and both ponding and rearing technique will continue. However the pinhead problem may be related to the quality of egg resulting from female adult chinooks held in the high summer water temperature on the Puntledge River.

7) Approximately 27 miles of underutilized river system exists upstream of the diversion dam in the upper Puntledge River and Comox Lake (The upper limit of watershed anadromous salmonid migration). The potential for colonizing this area is high. However it will depend on research into providing an effective guiding system to divert downstream migrant smolts around the powerhouse intake works. An effective smolt guiding system may be possible without resorting to the efficient, but costly louvre system which was proposed by the department as a remedial measure in the 1950's.

ACKNOWLEDGEMENTS

Material for this report was collected over a period of years. Appreciation is extended to:

Vern George

Trevor Bolt

Dave Marshall

and other Fisheries Service Personnel who assisted in the field over the period covered in this report. I am also grateful to Barry Minaker for help in table preparation.

LITERATURE CITED

ANON. 1958. Puntledge River, Downstream Salvage Programme. Dept. of Fisheries, Canada, Vancouver, B. C. 10 p.

ANON. 1958. Puntledge River. The Fisheries Problems associated with the power development of the Puntledge River, Vancouver Island, B. C. Dept. of Fisheries, Canada, Vancouver, B. C.

ARMSTRONG, R. W. 1973. An evaluation of Chinook salmon egg collection and hatchery incubation methods used during 1971 and 1972. Tech. Rpt. Ser. No. PAC/T - 73 - 11. Southern Op. Br. Pac. Region. 48p.

ARMSTRONG, R.W., and A.W. ARGUE. 1977. Trapping and coded-wire tagging of wild Coho and Chinook juveniles from the Cowichan River System, Tech. Rpt. Ser. PAC/ T - 77 - 14, Field Op - Dir., Pac. Region.

BOUCK, GERALD R., CHAPMAN, G.A., P.W. SCHNEIDER, JR., and D.G. STEVENS, 1975. Effects of Holding Temperatures on Reproductive Development in Adult Sockeye Salmon (O. Nerka). Northwest Fish Culture Conference. Otter Rock, Oregon. pp. 25 - 30.

CHAPMAN, GARY A. 1970. Effects of Temperature During a Simulated Migration of Adult Sockeye Salmon (Oncorhynchus nerka). U.S./E.P.A. In "Northwest Fish Culture Conf." Portland, Oregon, Dec. 1970. pp. 106 - 107.

COUTANT, C.C. 1970. Thermal resistance of adult coho (O.Kisutch) and jack chinook (O. Tschawytscha) salmon, and adult steelhead trout (S. Gairdneri) From the Columbia River. Batelle Northwest Lab. Doc. BNWL - SA - 3094, Richland, Wa.

EBEL, W.J. 1974. Marking Fishes and Invertebrates III. Coded wire tags useful in automatic recovery of chinook salmon and steelhead trout. Mar. Fish. Rev. 36(7) : 10 - 13.

HOLT, R.A., J.E. SANDERS, J.L. ZINN, J.L. FRYER, and K.S. PILCHER. 1975. Relation of water temperatures to Flexibacter Columnaris infection in steelhead trout (S. Gairdneri), coho (O. Kisutch) and chinook (O. Tschawytscha) salmon. J.Fish. Res. Bd. Can. 32 : 1553 - 1559

HUBLOV, W.F. 1963. Oregon Pellets. Prog. Fish. Cult. 25(4) : 175 - 180.

JEFFERTS, K.B., P.K. BERGMAN, and H.F. FISCUS. 1963. A coded wire identification system for macro-organisms. Nature (Lond.) 198 (4879) : 460-462.

KNITTEL, M.D. 1972. Topical Application of Malachite Green for control of common Fungus infections in adult spring chinook salmon. Prog. Fish Cult. Vol. 28, 51 - 53.

LISTER, D.B. 1968. Progress Report on Assessment of the Puntledge River Spawning Channel June, 1965 to May 1968. Dept. of Fisheries of Canada. Resource Dev. Br., Vancouver, B. C.

MARSHALL, D.E. 1973. Progress Report on The Puntledge River Program 1971 and 1972. Can. Dept. of Envir., Fish and Mar. Serv., Pac. Reg. Tech.Rpt. 1973 - 8. 53 p.

PAINE, J.R., F.K. SANDERCOCK and B.A. MINAKER. 1975. Big Qualicum River Project 1972 - 1973. Southern Op. Br., Pac. Region, Tech. Rept. Ser. No. PAC/T - 75 - 15.

SANDERCOCK, F.K. and B.A. MINAKER. 1975. Big Qualicum River Project 1973 - 1974. Southern Op. Br., Pac. Region. Tech. Rpt. Ser. No. PAC/T - 75 - 16.

UDEY, L. R., J.L. FRYER and K.S. PILCHER. 1975. Relationship of water temperature to Ceratomyxosis in rainbow trout (Salmo Gairdneri) and coho salmon (O. Kisutch). J. Fish Res. Bd. Canada 32 : 1545 - 1551.

WEBER, D. and G.J. RIDGWAY. 1967. Marking Pacific salmon with tetracycline antibiotics. J. Fish. Res. Bd. Canada 24 = 849 - 865.

WHITHLER, F.C. 1972. Research needs for intensive management of British Columbia Steelhead, Fish. Res. Bd. Canada. Cir. No 92. 41 pp.

WOLD, EINAR. 1970. Optimum temperature for incubating steelhead eggs. U.S. Bureau of Sport Fisheries and Wildlife. In "Northwest Fish Culture Conf." Portland, Oregon, Dec. 1970. pp. 82 - 85.

WOOD, J.W. 1974. Diseases of Pacific Salmon Their Prevention and Treatment, State of Washington Department of Fisheries Hatchery Division, 2nd. ed. 82 p.

Table 1. 1972 Brood basket plant - spawning channel.

Date	Location*	No. of eggs counted L.	No. of eggs counted D.	No. of alevin counted L.	No. of alevin counted D.	Percent survival
Nov. 20, 1972	Section 1					
	Right bank	76	14			86
	Left bank	82	17			82
	Section 2					
	Right bank	98	19			78
	Left bank	82	18			82
	Section 3					
	Right bank	86	14			86
	Left bank	76	22			76
Dec. 18, 1972	Section 1					
	Right bank	28	15	52	6	79
	Section 2					
	Right bank	18	21	51	4	69
	Section 3					
	Right bank	24	25	48	3	72
Feb. 20, 1972	Section 1					
	Center	0	32	68	0	68
	Section 2					
	Center	0	90	6	4	6
	Section 3					
	Center	0	100	0	0	0

*Note : - Section 1 is the lowest section of the channel.
- Right bank is facing downstream.
L = live.
D = dead.

Table 2. 1974 Brood basket plant - spawning channel.

Date	Location	No. of eggs counted	No. of dead eggs counted	Percent survival
Nov. 13, 1974	Section 3			
	Right bank	100	30	70.0
	Left bank	100	15	85.0
	Section 2			
	Right bank	100	17	83.9
	Left bank	100	21	79.0
	Section 1			
	Right bank	100	4	96.0
	Left bank	98	8	91.9
	Control			98.1
Dec. 23, 1974	Section 3			
	Right bank	100	11	89.0
	Left bank	100	100	0
	Section 2			
	Right bank	99	65	34.5
	Left bank	100	89	11.0
	Section 1			
	Right bank	100	64	36.0
	Left bank	100	53	47.0
	Control			95.0
March 10, 1975	Section 3	100	100	0
	Section 2	100	79	21.0
	Section 1	100	56	44.0

Table 3. 1974 Brood basket plant = fry survival of control group in incubator.

Developmental stage	No. of eggs	No. mortalities	Mortalities	Percent survival
Fertilization	8,205			
Eyed	8,042	163	163	98.0%
Alevin	7,952	90	253	96.9
Swim-up	7,762	190	443	94.6

Table 4. Distribution of summer-run chinook escapement in the Puntledge River : 1965 - 1976.

Return year	Spawned in river	Entered channel				Total escapement
		Held for egg-take	Prespawning mortality[+]	Spawned in channel	Total	
1965	34		12	236	248	282
1966	24		76	551	627	651
1967	7		219	453	672	679
1968	20		83	241	324	344
1969	59		17	215	232	291
1970	27		23	387	410	437
1971	25		18	376	394	419
1972	85	50	35	255	340	425
1973	71	23	24	208	255	326
1974	75	149	16	113	278	353
1975	75	160	28	128	316	391
1976	90	138	29*	16*	183*	273*

+Prespawning mortality does not include holding mortality.
*These figures are estimates. There was extensive predation in the channel in 1976.

Table 5. Fry emigration from the Puntledge River and spawning channel : 1956 - 1976.

Brood year	Migrating from the river above diversion dam	Migrating below diversion dam[+]	Migrating from the channel: Trapped for rearing[a]	Migrating from the channel: To the river	Hatchery release	Total release
1955	90,745					90,745
1956	102,319					102,319
1957	498					498
1958	15,296					15,296
1959	71,814					71,814
1960	47,313					47,313
1965		4,129		47,800		51,929
1966		2,914		84,144		87,058
1967		850		244,000		244,850
1968		2,429		186,000		188,429
1969		7,164	4,200	60,800	2,526	70,490
1970		3,279	86,071	150,140	47,568	200,987
1971		10,322	33,100	18,200	5,070	33,592
1972		8,622	32,548	34,338	58,465*	101,425
1973		6,624		28,453	13,565	48,642
1974		12,288		9,838	39,848	61,974
1975		9,216		54,751	180,044	244,011
1976		11,520		5,422	110,000	236,974

[a] exclude in total estimate.

[+] This estimate based on egg-to-fry survival rate of 0.08 percent, fecundity = 4,600 eggs/female and the number of females observed spawning in the river.

* 5,000 super smolts.

Table 6. No. of female spawners, potential egg deposition and egg-to-fry survival in the Puntledge spawning channel : 1965 - 1976.

Brood years	Female spawners	Average length female spawners (mm)	Potential egg deposition*	Fry production	Percent egg-to-fry survival
1965	92	683	437,000	48,000	10.9
1966	46	681	211,000	84,000	39.9
1967	147	672	648,000	243,000	37.6
1968	89	696	415,000	186,000	45.0
1969	46	649	193,000	65,000	33.7
1970	175	712	853,000	213,000	26.1
1971	94	690	439,000	51,000	11.6
1972	115	686	527,000	67,000	12.7
1973	63	685	232,000	28,000	12.2
1974	26	703	122,000	9,800	8.1
1975	20	682	84,000	55,000	64.8
1976	3	688	15,000+	5,422	36.3

*fecundity equations used : 1965-1972 -5,697 + 15.04 (hyp. length).
1973-1975 -4,071 + 12.40 (hyp. length).

+This egg deposition is an estimate - the actual no. of successful spawners is unknown due to extensive predation in the channel.

Table 7. Timing of fry migrations from the river and spawning channel : 1955 - 1976.

Brood year	Date			ATU °C at median date
	Migration began	50% fry migration	Migration ended*	
1955	April 5	April 22	July 28	-
1956	March 15		May 30	-
1957	March 22	April 18	June 4	
1958	March 12	April 4	May 26	
1959				
1960				
1965	Feb. 4	March 14	July 6	1,114
1966	Feb. 15	March 23	July 9	1,156
1967	March 1	March 23	April 29	1,112
1968	March 2	April 23	June 27	1,048
1969	Feb. 17	March 13	June 3	1,128
1970	Feb. 16	April 11	June 17	1,105
1971	Feb. 15	April 11	May 22	959
1972	Feb. 12	April 6	June 25	1,074
1973	Feb. 20	April 11	July 2	-
1974	Feb. 26	April 5	July 2	1,211
1975	Feb. 3	April 12	July 5	1,221
1976	Jan. 19	Feb. 15	June 28	-
Average	Feb. 24	April 6	June 19	1,113

*In later years enumeration ceased when 1st adult reached the channel.

Table 8. Annual escapement of chinook, coho, chum and pink salmon to the Puntledge River : 1949 - 1976.

Return year	Number of returning				
	Summer-run chinook	Fall-run chinook	Coho	Chum	Pink
1949	5,000	2,000	2,000	20,000	5,500
1950	2,000	4,500	1,200	20,000	6,000
1951	2,400	3,600	3,000	55,000	130,000
1952	2,400	1,600	4,000	18,000	16,000
1953	1,380	2,100	6,000	42,000	10,000
1954	5,200	6,000	6,000	26,000	16,000
1955	1,200	4,500	3,000	45,000	16,000
1956	600	900	4,500	18,000	6,000
1957	450	2,400	5,500	28,000	20,000
1958	2,000	6,000	5,000	25,000	35,000
1959	1,500	2,000	1,600	42,000	2,000
1960	1,400	1,800	3,000	27,000	3,250
1961	225	1,275	3,150	20,000	9,000
1962	400	1,175	2,500	25,000	2,500
1963	575	900	8,000	70,000	7,800
1964	160	590	11,000	45,000	700
1965	282	850	1,400	15,000	1,500
1966	651	550	3,000	24,000	2,000
1967	679	200	1,500	20,000	1,200
1968	344	285	1,100	55,000	2,100
1969	291	185	1,400	27,000	100
1970	437	225	2,500	34,000	1,000
1971	419	150	4,000	14,000	300
1972	425	200	1,300	60,000	2,500
1973	326	500	1,500	55,000	700
1974	353	225	7,000	45,000	850
1975	391	500	2,500	27,500	400
1976	273	327	1,000	35,000	350

Table 9. Sex composition of summer-run chinook adults entering the Puntledge channel : 1965 - 1976.

Year	Females		Males		Escapement to channel
	Number	%	Number	%	
1965	101	40.7	147	59.3	248
1966	64	10.2	563	89.8	627
1967	238	35.4	434	64.6	672
1968	136	41.9	188	58.1	324
1969	50	21.6	182	68.4	232
1970	190	46.3	220	53.7	410
1971	101	25.6	293	74.4	394
1972	169	49.7	171	50.3	340
1973	76	29.8	179	70.2	255
1974	118	42.4	160	57.6	278
1975	112	35.4	204	64.6	316
1976	73*	39.9	110*	60.1	183
Average	119	33.3	238	66.7	

*estimates.

Table 10. Age composition of marked summer-run chinook adults in the Puntledge River : 1975 - 1976.

Return year	Sex	Fish aged				
		2	3	4	5	All
1975	Males	0	51	12	0	63
	%		81	19		
	Females		2	5	0	7
	%		29	71		
	Both	0	53	17	0	70
	%		76	24		
1976	Males	4	25	26	3	58
	%	7	43	45	5	
	Females	0	0	31	3	34
	%			91	9	
	Both	4	25	57	6	92
	%	4	27	62	7	

Table 11. Average length of summer-run adults : 1955 - 1976.

	Males		Females		Males and females	
Year	Sample size	Average length (mm)	Sample size	Average length (mm)	Sample size	Average length (mm)
1955					142	853
1956					59	813
1965	99	570	76	683	175	619
1966	100	547	41	681	141	605
1967	100	595	100	672	200	634
1968	163	592	132	696	295	639
1969	100	596	46	649	146	613
1970	211	564	174	712	385	631
1971	106	573	92	690	198	627
1972	102	610	115	686	217	650
1973	100	584	65	685	165	623
1974	145	600	108	703	253	644
1975	204	585	112	682	316	619
1976	95	580	71	703	166	633
Overall*	1,525	583	1,132	690	2,657	629

*excludes 1955 - 1956 samples which did not include jacks.

Table 12. Average weight of summer-run chinook adults at the Puntledge River : 1955 - 1973.

	Males		Females		Males & females	
Return year	Sample size	Average weight (kg)	Sample size	Average weight (kg)	Sample size	Average weight (kg)
1955					142	8.13
1956					59	7.63
1972	99	4.18	100	5.58	199	4.90
1973	98	3.77	73	5.22	171	4.40

Table 13. Summary of egg-take data for summer chinook Brood years 1972 - 1976.

Year	Females held	Holding mortalities	Females stripped	Egg-take dates First	Egg-take dates Last	Total eggs
1972	24	8[*]	20[a]	Oct. 1	Oct. 18	67,523
1973	12	0	12	Oct. 11	Oct. 17	43,152
1974	76	38[b]	28	Oct. 1	Oct. 22	123,206
1975	77	1	76	Oct. 1	Oct. 16	315,352
1976	63	1	62	Sept. 27	Oct. 18	267,777

[a] Two of these were freshly dead; another two were partly spawned fish taken from the channel.
[b] In addition, ten fish were stolen from the holding pens.
[*] Two of these were fully ripe when they died; they were stripped and incubated.

Table 14. Incubation of summer-run chinook eggs : Brood years 1972 - 1976.

Brood years	No. of eggs	Average egg/tray	Mean °C at egg-take	% mortality to			Fry ponded
				Eyeing	Hatching	Ponding	
1972	67,523	3,553	12.2	17.1	20.0	-	61,860
1973	43,152	6,164	12.6	13.1	19.6	20.8	34,646
1974	123,206	4,400	14.4	12.9	14.1	21.6	101,828
1975	315,352	5,524	15.0	6.5	7.4	10.9	289,063
1976	267,777	5,697	13.3	12.6	8.8	11.4	240,190

Table 15. Average length, fecundity and egg retention of female summer-run chinooks at the Puntledge River (1966-1976).

Brood year	Sample size	Average length (mm)	Average fecundity (eggs)	Average no. eggs stripped (eggs)	Percent egg retention
1966	10	680	4,486		
1967	27	683	4,589		
1972	28	685	4,513	3,515	22.2
1973	10	683	4,260	3,596	15.6
1974	-	-	-	4,406	-
1975	11	719	4,772	4,148	13.1
1976	12	704	4,745	4,310	9.2
Average	98	691	4,564	3,995	12.5

Table 16. Ponding of summer-run chinook fry : Brood years 1969-1975.

Brood year	Fry ponded	Days incubation	Ponding period	Mean ponding date	Size at ponding (fish/lb)	Mean ATU °C at ponding
1969	4,160*		Mar. 20-Apr. 4	Mar. 23	1,121	
1970	61,792*		Mar. 26-Apr. 19	Apr. 12	892	
1971	32,990*		Mar. 18-May 22	Apr. 15	1,094	
1972	94,408+	135	Feb. 21-Apr. 14	Mar. 6	1,077	734
1973	34,676	147	Mar. 5-Mar. 18	Mar. 8	1,063	809
1974	101,828	125	Jan. 13-Mar. 7	Feb. 26	1,274	815
1975	289,063	132	Jan. 23-Mar. 8	Feb. 12	959	947
1976	240,190	120	Dec. 24-Feb. 4	Jan. 15	1,130	991

*Trapped from channel.
+32,548 fry trapped from channel.

Table 17. Growth and food conversion of summer-run chinook during rearing : Brood years 1969 - 1976.

Brood year	Total weight at ponding (lb)	Total feed (lb)	Total weight at release (lb)	Conversion rate	Growth rate %/day	Size of fish at ponding (fish/lb)	Size of fish at release (fish/lb)	ATU °C at release
1969	3.8	144.3	57.8	2.67		1,121		
1970	69.3	682.2	402.6	2.04		892		
1971	30.2	523.8	233.2	2.58	2.79	1,094	102.0	1,852
1971*	38.9	1,307.9	724.3	1.91	1.17	281	7.0	4,831
1972	86.2	1,198.9	737.2	1.84	2.19	1,095	79.0	1,808
1973*	32.6	683.0	274.0	2.49		1,063	49.0	2,429
1973* cont.	274.0	4,784.0	3,090.0	1.72	1.22	49	4.4	5,704
1974	79.9	1,113.3	375.9	3.77	2.07	1,274	106.0	2,196
1975	285.0	2,724.0	2,154.0	1.46	1.87	1,015	83.6	2,092
1976	183.0	2,835.0	1,395.0	2.40	1.47+ 2.27++	991	87.3	2,384

* super smolts.

\+ "burrows"-reared.

++ tub-reared.

Table 18. Rearing period of summer-run chinook, Brood years 1969-1975.

Brood year	Mean ponding date	Release date	Mean rearing period (days)
1969	Mar. 23	July 27	123
1970	April 12	Aug. 15	125
1971	April 15	July 9*	85
1971+	July 9	May 17	316
1972	Mar. 6	June 20	120
1973+	Mar. 8	May 20	447
1974	Feb. 26	June 26	120
1975	Feb. 12	June 25	133
1976	Jan. 15	June 20	156

*mean of two release dates.
+"super" smolts.

Table 19. Rearing mortality of summer-run chinook : Brood years 1969 - 1975.

Brood year	Fry ponded	Accountable mortality		Unaccountable losses		Overall mortality		Fingerlings released
		Number	%	Number	%	Number	%	
1969	4,160	1,233	29.6	401	9.6	1,634	39.3	2,526
1970	61,792	-	-	-	-	14,224	23.0	47,568
1971	32,990	-	-	-	-	2,201	6.7	19,831
1971	10,957	4,735	43.2	1,152	10.5	5,887	53.7	5,070*
1972	94,408	15,416	16.4	20,527	21.7	35,943	38.1	58,465
1973	34,676	12,964	37.4	6,682	19.3	19,646	56.6	
1973	15,030			1,465	9.7	1,465	9.7	13,565*
1974	101,828	22,626	26.1	35,354	34.7	61,980	60.8	39,848
1975	289,063	81,766	28.3	27,253	9.4	109,019	37.7	180,044
1976	240,190	86,542	36.0	28,804	11.9	124,844	52.0	115,346

* "super" smolts.

Table 20. 1976 - summer chinook pinheads in tubs.

Tub #1	Period	Number	Survival	A.T.U. Days	Eggs in tray	Fish/lb	Mean wt(g)	Mean L+(mm)	
	April 13	3,252				750			Fed vitamins, liver,
	May 3	1,664							O.M.P. plus plankton
		4,916							
	May 3								
	mortal	4,270							
	May 11	3,796							
	May 28	3,004	29.4			404			
Tub #2									
1	April 13	3,253				750			Fed liver, O.M.P.
	May 3	2,080							plankton
		5,333							
	May 3-								
	mortal	4,808							Transfer to tub #1

Table 21. Estimated catch and escapement of 1972 brood summer chinook CWT's in 1974, 1975, 1976, and 1977 (preliminary, A.W. Argue).

	Puntledge 4/1				
Catch Area	1974	1975	1976	1977	Total
Alaska - U.S.[a]		2 (1)	3 (6)		5 (1)
North & Central Coast	25 (5)	43 (14)	15 (30)	4 (100)	87 (10)
West Coast Van. Is.	-	8 (3)	-	-	8 (1)
Wash. - U.S.[a]	-	-	-	-	-
San Juan	2 (4)	2 (4)	-	-	4 (4)
Johnstone St.	33 (6)	8 (3)	-	-	41 (5)
Georgia St.	466 (89)	237 (79)	32 (64)	-	735 (83)
Total (% at age)	526 (60)	300 (34)	50 (6)	4 (1)	880
% recovered	1.14	0.65	0.11	0.01	1.91
Total river escapement	3	68	83	-	154
% recovered	-	0.15	0.18	-	0.33
Total % recovered (C + E)	1.14	0.80	0.29	0.01	2.24
Catch / Escapement ratio	-	4.3/1	0.6/1	-	5.8/1

[a]Assumed C/S Alaska = 2.5 in 1976 and 1977
C/S Washington = 4.0 in 1977

Table 22. Escapement breakdown of fall-run chinooks returning to the Puntledge River : 1972 - 1976.

Return year	Fish			Females used for egg-take
	Total escapement	Held for hatchery	Left to spawn in river	
1972	200	41	159	7
1973	500	103	397	42
1974	225	2	223	1
1975	500	105	395	31
1976	327	28	299	5

Table 23. Age composition of fall-run chinooks spawning in the Puntledge River : 1975 - 1976.

Return year	Sex	Fish aged				
		2	3	4	5	All
1975	Males (n)	15	16	37	6	74
	%	20	22	50	8	
	Females (n)	0	0	23	10	33
	%	0	0	70	30	
	Both (n)	15	16	60	16	107
1976	Males (n)	0	12	6	4	22
	%		55	27	18	
	Females (n)	0	1	2	2	5
	%		20	40	40	
	Both (n)	0	13	8	6	27

Table 24a. Average length of fall-run chinooks returning to the Puntledge River : 1972 - 1976.

	Males		Females		Males & females	
Return year	Sample size	Average length (mm)	Sample size	Average length (mm)	Sample size	Average length (mm)
1972	26	644	16	753	42	685
1973	48	762	62	831	110	801
1974	6	756	3	862	9	791
1975	76	642	35	804	111	693
1976	23	730	5	801	28	743

Table 24b. Average weight of fall-run chinooks returning to the Puntledge River : 1972 - 1973.

	Males		Females*		Males & females	
Return year	Sample size	Average weight (kg)	Sample size	Average weight (kg)	Sample size	Average weight (kg)
1972	26	7.04	16	9.53	42	7.99
1973	48	11.44	62	13.07	110	12.35

*After stripping.

Table 25. Distribution of fall-run chinook spawning in the Puntledge River : 1968 - 1976.

Return year	Surveys made	Date of given survey	Spawners counted in river section*												
			1	2	3	4	5	6	7	8	9	10	11	12	All
1968	1	Oct. 18	0	5	24	9	14	35	5	5	30	25	78	-	230
1969	3	Oct. 22	0	32	6	0	24	18	0	14	15	30	29	0	168
1972	7	Oct. 17	0	30	7	0	0	13	10	0	9	7	11	-	87
1973	5	Oct. 15	0	75	12	24	10	36	13	14	10	25	73	10	302
1974	4	Oct. 24	0	11	41	22	5	31	26	8	11	24	43	-	222
1975	1	Sept. 25	0	60	0	11	0	0	0	0	1	0	1	0	73
1976	5	Oct. 14	4	14	94	6	7	13	9	11	2	1	4	2	93
Average			1	43	31	10	10	24	11	9	13	19	40	4	215
Distribution(%)			0.5	20.0	14.4	4.7	4.7	11.2	5.1	4.2	6.0	8.8	18.6	1.9	

*See Fig. 15 for river section map.

Table 26. Number of fish of all species and sex-composition of chinooks caught during netting of fall-runs for the hatchery at the Puntledge River : 1972 - 1976.

		Fish caught						
		Chinook						
Return year	Days netting	Adult males	Females (% total)	Jacks	Total	Coho	Chum	Pink
1972	10	23	19 (38.8)	7	49	-	-	-
1973	7	20	21 (35.6)	17	59	121	40	1
1974	3	7	3 (27.2)	1	11	97	18	1
1975	5	74	35 (21.2)	56	165	181	65	10
1976	7	33	5 (8.1)	24	62	99	14	2

Table 27. Holding mortality among fall-run chinooks used for egg-take : 1972 - 1976.

Return year	Fish held				Female mortality	
	Adult males	Females	Jacks	Total	Number	%
1972	22	16	3	41	12*	75.0
1973	41	62		103	20	32.3
1974	1	1		2	0	0
1975	55	35	15	105	4	11.4
1976	23	5		28	0	0

*3 of these fish were fully ripe when they died; their eggs were fertilized and incubated with partial success.

Table 28. Fall-run chinooks egg-take at the Puntledge River : 1972 - 1976.

Brood year	Females stripped	Egg-take dates		Total eggs	Fecundity minus retention
		First	Last		
1972	7*	Oct. 4	Oct. 18	32,804	4,686
1973	42+	Oct. 10	Oct. 24	214,902	5,117
1974	1	-	-	6,447	
1975	31	Oct. 4	Oct. 20	176,755	5,702
1976	5	Oct. 6	Oct. 18	23,455	4,691

*Three of these were dead prior to stripping.
+Two of these were dead prior to stripping.

Table 29. Incubation mortality of fall-run chinook at the Puntledge River : 1972 - 1976.

Brood year	Eggs incubated	Average egg/tray	% mortality to Eyeing	% mortality to Hatching	% mortality to Ponding	Fry ponded
1972	32,804	3,645	42.9	44.6	45.6	17,838
1973	214,902	5,241	29.3	31.6	38.9*	6,703
1974	6,447	3,224	53.8	55.0		--+
1975	176,755	4,777	8.8	9.9	10.9	157,423
1976	23,455	4,691	2.9	8.2	11.1	20,838

*Some fish stripped green and dead.

+Fish added to summer reared chinook pond.

Table 30. Rearing period and food conversion of fall-run chinook juveniles at the Puntledge hatchery 1972 - 1976 Broods.

Brood year	Total wt. of fish at ponding (lb)	Total feed (lb)	Total wt. of fish at release (lb)	Conversion rate	Size of fish at : Ponding (F/lb)	Ponding g	Release (F/lb)	Release g	ATU of release (°C)	Mean rearing period (days)	Growth rate %/day
1972	17.5	187.8	125.2	1.74:1	1,013	.45	70	6.49	1,783.0	118	2.27
1973	178.3	1,825.8	1,672.6	1.22:1	891	.51	77	5.90	1,856.0	102	2.40
1975	183.7	2,058.3	1,395.0	1.70:1	852	.53	91	4.99	1,975.5	119	1.88
1976*	22.0	617.5	358.3	1.83:1	951	.48					

*held over for extended rearing (values to June 27/77).

Table 31. Percentage rearing mortality of fall-run juveniles at the Puntledge River : 1972 - 1976.

Brood year	No. ponded	% mortality Accountable	% mortality Unaccountable	Total	No. released	Date released
1972	17,888	3.9	46.6	50.5	8,759	June 18
1973	146,073	11.8	18.4	30.2	101,963	June 27
1974	-	-	-	-	-	
1975	157,423	9.1	10.0	19.7	126,831	June 21
1976	20,838	held over for extended rearing				

Table 32. Estimated catch and river escapement of 1973 brood fall chinook CWTs in 1975, 1976, and 1977. (Preliminary, A.W. Argue)

	Puntledge 3/2				
Catch Area	1975	1976	1977	1978	Total
Alaska - U.S.	2 (<1)	88 (11)	90 (27)	NA[a]	180 (9)
North & Central Coast	68 (8)	374 (45)	101 (30)	NA	543 (28)
West Coast Van. Is.	-	17 (2)	5 (2)	NA	22 (1)
Wash. - U.S.	5 (1)	- -	4 (1)	NA	9 (<1)
San Juan	-	5 (<1)	-	NA	5 (<1)
Johnstone St.	110 (14)	35 (4)	45 (14)	NA	190 (10)
Georgia St.	626 (77)	315 (38)	88 (26)	NA	1,029 (52)
Total (% at age)	811 (41)	834 (42)	333 (17)	NA	1,978
% recovered	2.05	2.10	0.84	NA	4.99
Total river escapement	25 (22)	21 (20)	65 (58)	NA	111
% recovered	0.07	0.05	0.16	NA	0.28
Total % recovered (C + E)	2.12	2.15	1.0	NA	5.27
Catch / Escapement ratio	29/1	42/1	5.2/1	NA	17.8/1

[a]Not available.

Table 33. 1976 brood Morrison Creek coho-rearing.

Date (week ending)	Number	Operation	Size (fish/lb)	A.T.U. (°C)
April 4/77	2,032	Ponded fry	1089.25	122.8
April 11	16,152	"		177.3
April 18	24,335	"	1037.00*	228.6
April 25	25,475	"		285.3
May 2			554.00*	349.1
May 9			540.70	417.3
May 16				419.0
May 23			389.00	567.0
May 30				644.1
June 6				723.0
June 13			202.00*	814.9
June 20				921.9
June 27			149.30	1033.4

*Wet weight.

Table 34. Morrison Creek : 1976 brood coho fry trapping for Puntledge hatchery rearing program.

Date (week ending)	Coho fry	Accum. total	Coho* pre-smolts	Accum. total	Pinks*	Temp. (°F)
Feb. 21			8	8	4	43.0
Feb. 28						
March 7			6	14	1	38.0
March 14	1	1	6	20	6	38.0
March 21	29	30	48	68	265	38.0
March 28	351	381	47	115	3,912	38.5
April 4	1,660	2,041	18	133	5,752	42.0
April 11	14,171	16,212	49	182	6,750	46.0
April 18	8,222	24,434	50	232	134	44.0
April 19	1,181	25,615+	8	240	2	46.0
				Total Pink	16,826	
May 17	1,200	released*	32	272		
May 25	750	" *	15	287		
June 1	500	" *	3	290		

112 Lamprey released
82 Sculpin "
2 Trout "

+ held for rearing

* released after trapping

Table 35. Details of juvenile coho rearing program : Brood 1976.

Date (week ending)		Pond flow (gal./min)	Weekly temp. (°C)	Food ounces/day of pellet size mash	1/32	3/64	1/16	3/32	Mean* length (mm)	Mean* weight (gm)
March	21	5 tub	5.9	1						
	28	5 tub	6.2	1						
April	4	100 pond	6.7	2					36.64	0.41
	11	150	8.0	8						
	18	150	8.0	5	5					
	25	150	7.5	8	8					
May	2	250	9.1	6	10					
	9	250	10.0		35				42.54	0.84
	16	250	10.0		28	14				
	23	250	11.1		28	14			46.75	1.16
	30	250	11.3			56	8			
June	6	350	11.0			60	17			
	13	350	13.1			39	38			
	20	450	15.0			16	103			
	27	500	16.1			87	69		62.36	3.04

Total food	273.0 lb.
Total weight at ponding	23.4 lbs.
Total weight June 27/77	166.3 lbs.
Total gain	142.8 lbs.
Conversion	1.9:1

*Sample size 100 fish.

Table 36. Puntledge River adult steelhead trapping summary 1976/77 brood.

Date	Daily total	Accum. total	Released	
			Above dam	Holding pond
Nov. 8	1	1	1	
Jan. 3	1	2	1	
Feb. 18	1	3		1
April 30	1	4		1
May 4	1	5		1
May 7	1	6		1
May 15	2	8		2
May 24	2	10	2	
June 2	2	12	2	
June 11	Trap out			

Table 37. Puntledge River adult steelhead capturing & egg-take.

Captured by angling & seining	Females	15
	Males	21
	Total	36
Captured by trap at spawning channel	Females	3
	Males	3
	Total	6
Total for hatchery stock		42
Egg-take	Females stripped	14
	Males used	19
Mortality	Females	1
Kelts released	Females	3
	Males	5
Total eggs taken		53,776
Total eggs hatch to ponding		49,100
Percent hatched		91.3%

Table 38. Puntledge River spawning channel-migrant trapping 1976 Brood.

Date week-ending		Chinook fry	Steelhead fry 1977 Brood	Steelhead smolts	Trout fingerlings
Jan.	19	2			
Feb.	8	147		1	6
	15	716		4	
	22	942			10
March	1	1,009			14
	8	1,091			15
	15	1,121			17
	22	1,134			18
	29	1,141			20
April	5	1,144			25
	12	1,152			30
	19	1,157		5	32
	26	1,160		14	39
May	3	1,162	8	18	43
	10	1,163	405	19	45
	17	1,164	630	21	48
	24	1,169	1,000		54
	31	1,181	1,187		57
June	7	1,183	1,197		
	14	1,186	1,238		
	21	1,192	1,240		
	28	1,205	1,417	22	67
July	5		1,477*		88
	13		1,483*		146
Coefficient		x 4.5	x 4.5	x 4.5	x 4.5
		5,422	6,673	99	657
Fyke net			910*		
Seined from channel			1,783*		
Total		5,422	9,366	99	657

*fry ponded.

Table 39. 1977 Brood summer-run steelhead - Puntledge juvenile rearing summary.

Date	Number	Operation	Size (fish/lb)	A.T.U. (°C)
May 11/77	52	Fry pond from channel		
30	1,286	" "		
June 15	1,441	" "	1,017.9	
30	1,663	" "	316.3	
July 13	1,694	Last fry trapped from channel		
23-27	1,783	Seined from channel		
Total	3,477	Fry rearing	149.1	

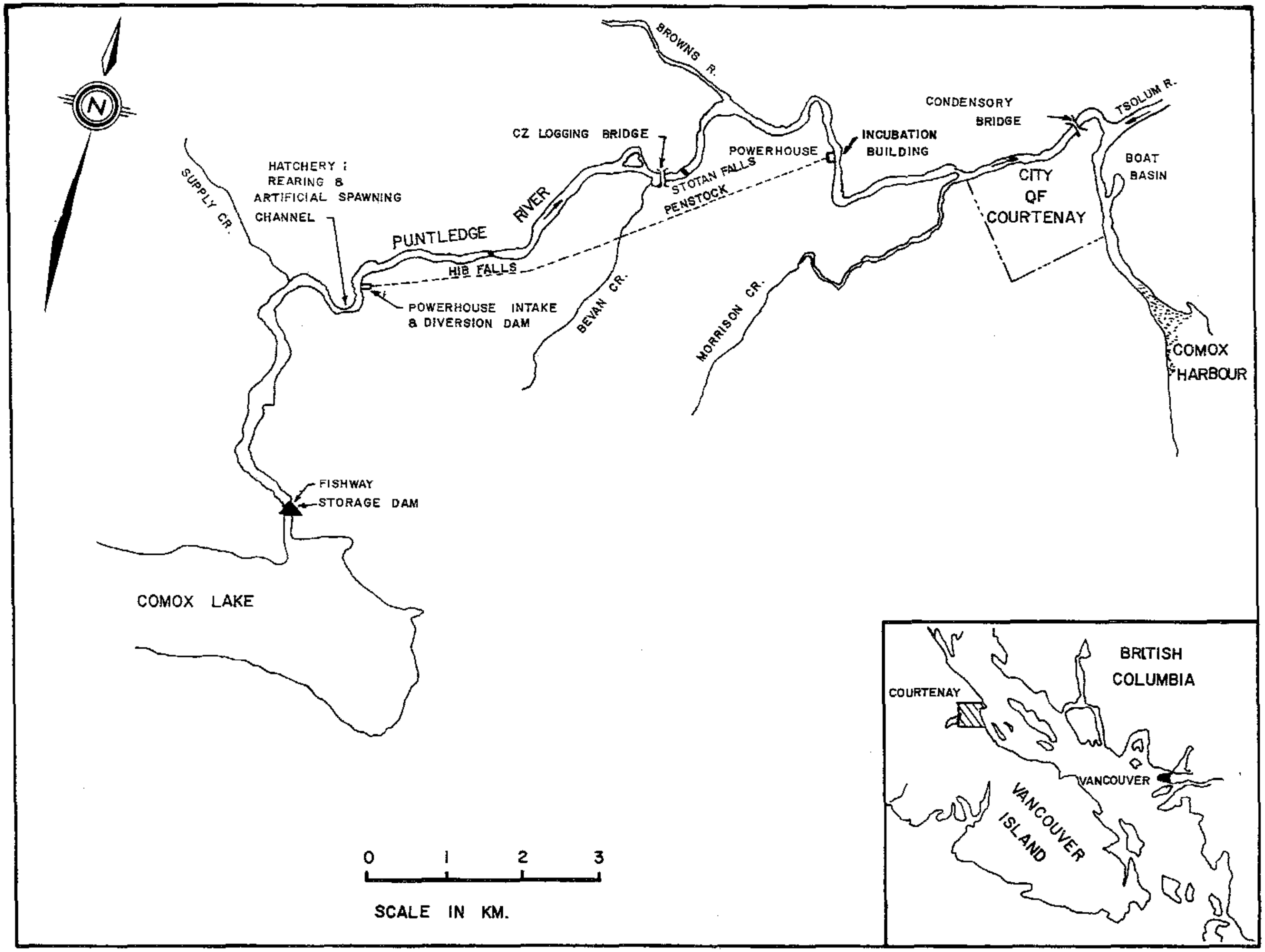


FIGURE 1 MAP OF THE PUNTLEDGE RIVER SHOWING THE HYDRO-ELECTRIC DEVELOPMENT SCHEME AND LOCATION OF THE SPAWNING CHANNEL AND HATCHERY.

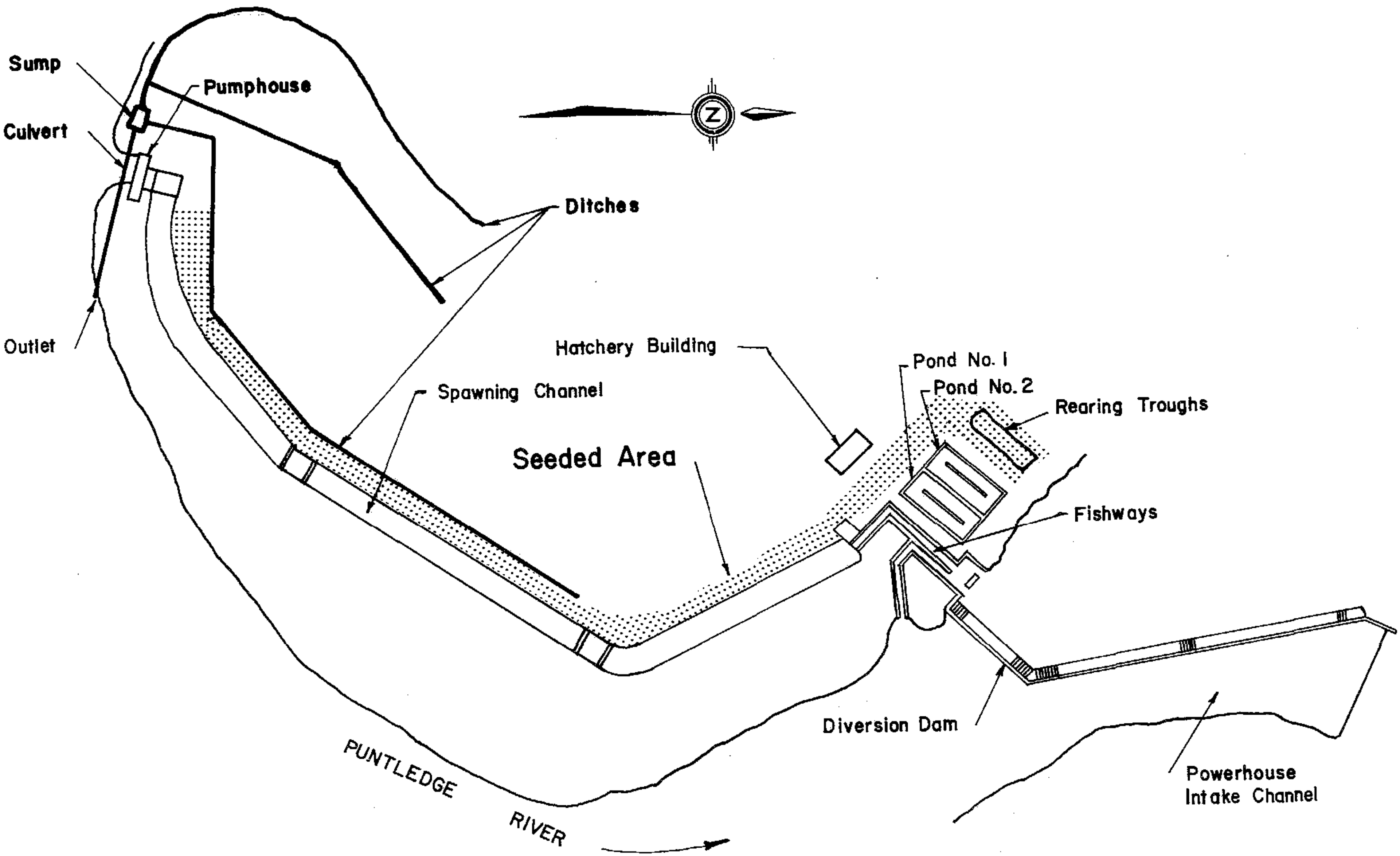


FIG. 2 PUNTLEDGE RIVER SPAWNING CHANNEL AND REARING PONDS

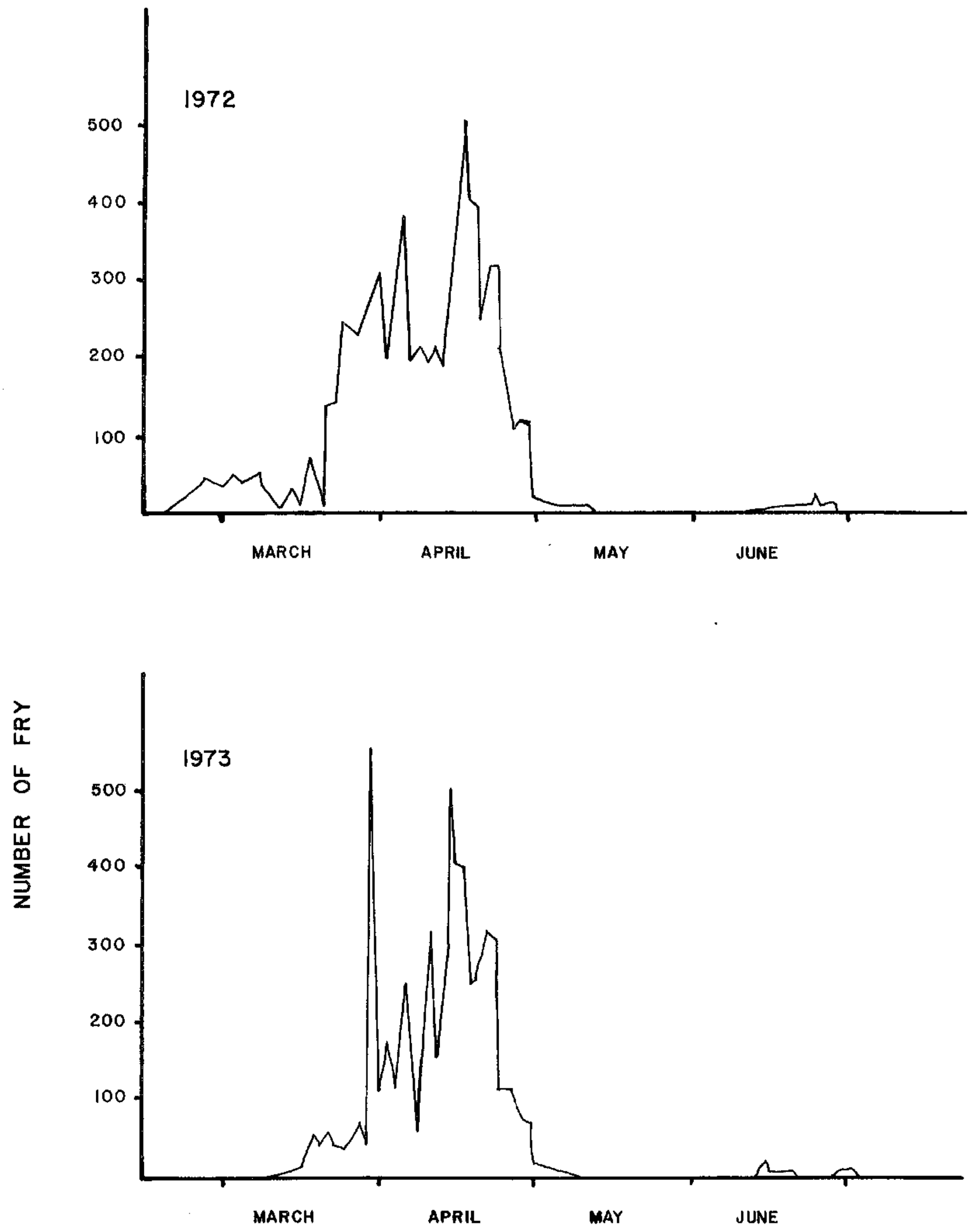


FIG. 3a : TIMING OF JUVENILE CHINOOK SALMON EMIGRATION FROM THE SPAWNING CHANNEL (TRAP CATCH COEFFICIENT = 4.53)

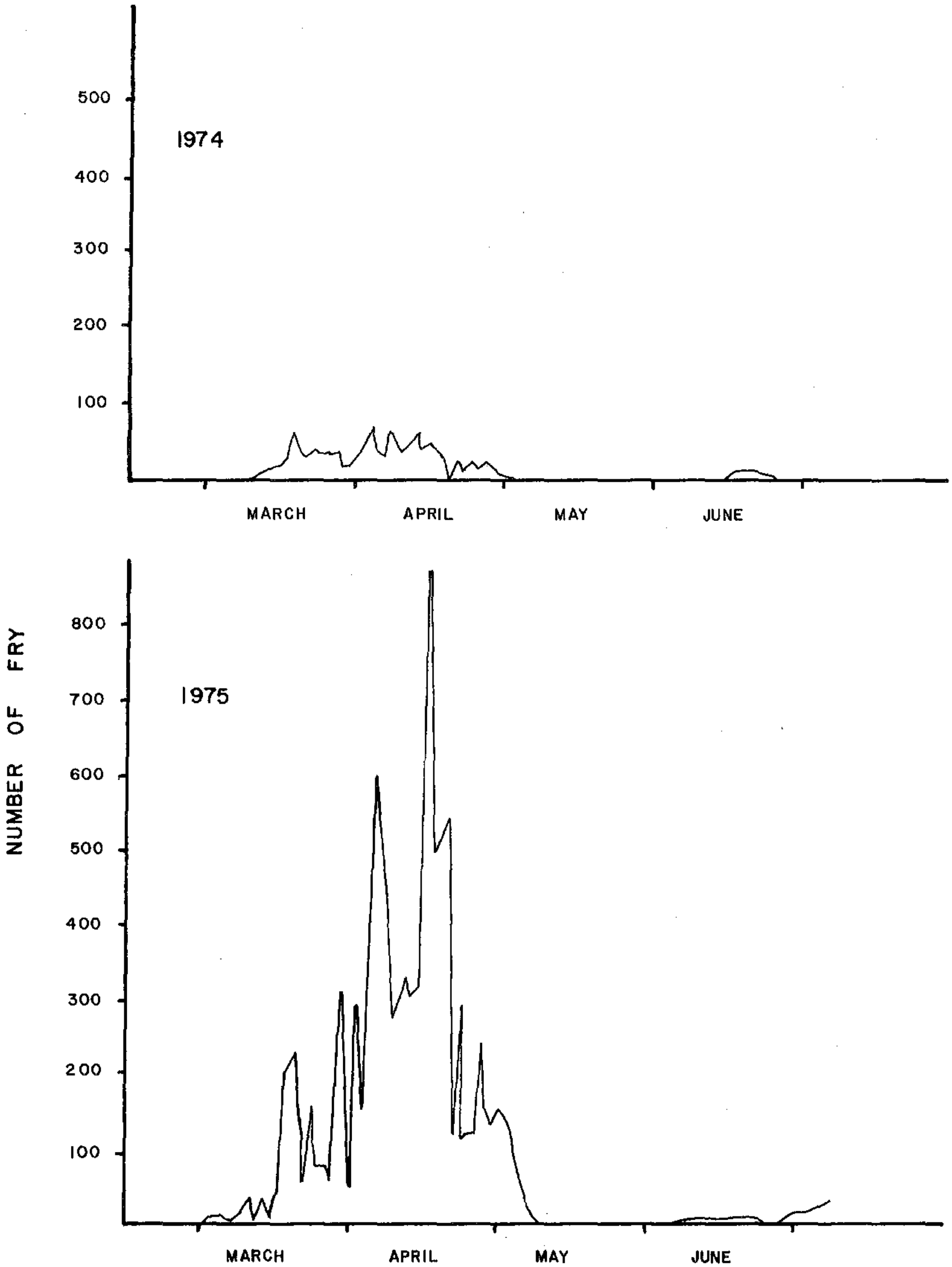


FIG. 3b: TIMING OF JUVENILE CHINOOK SALMON EMIGRATION FROM THE SPAWNING CHANNEL
(TRAP CATCH COEFFICIENT = 4.53)

FIG. 4. SIZE (FISH / lb.) OF JUVENILE CHINOOK SALMON EMIGRATING FROM THE SPAWNING CHANNEL.

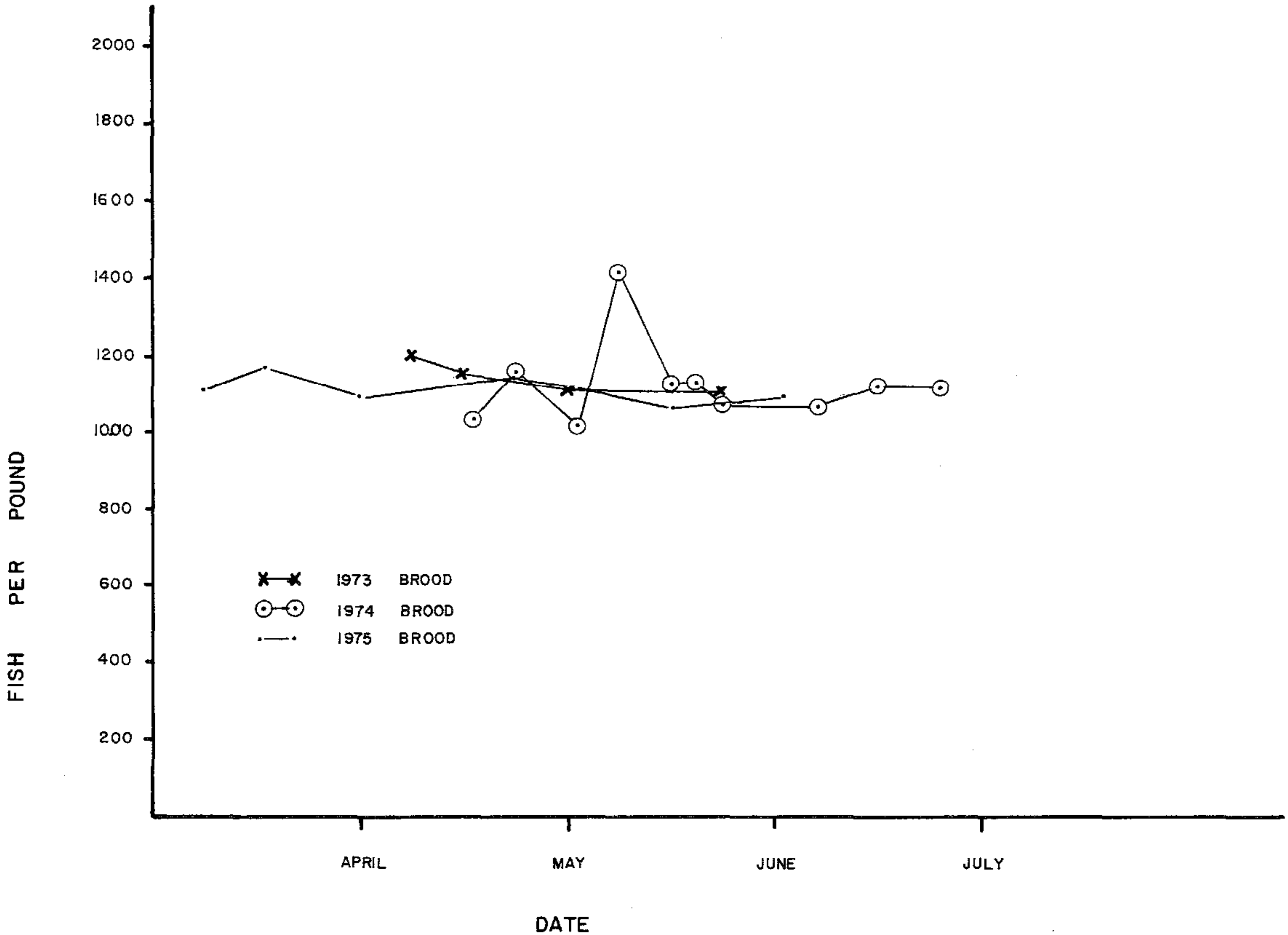


FIG. 5. FEMALE ADULT LENGTH (MM) VERSUS FECUNDITY (SUMMER CHINOOK) : BROODS 1966 - 1976
(SEE TABLE 15)

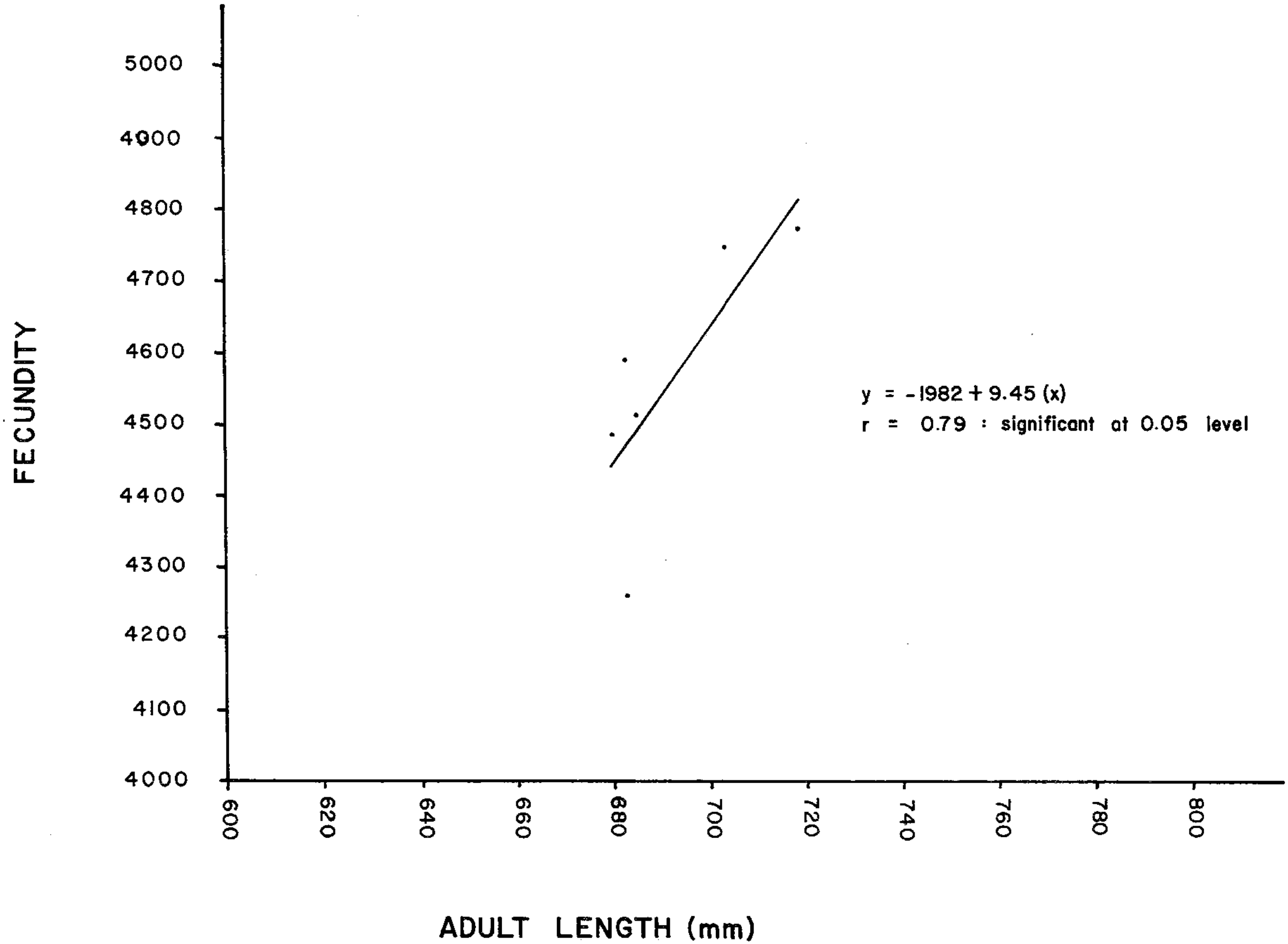


FIG. 6 SUMMER CHINOOK EGG SURVIVAL DURING INCUBATION VERSUS NUMBER OF EGGS TAKEN PER SPAWNING DAY: BROODS 1972 - 1976

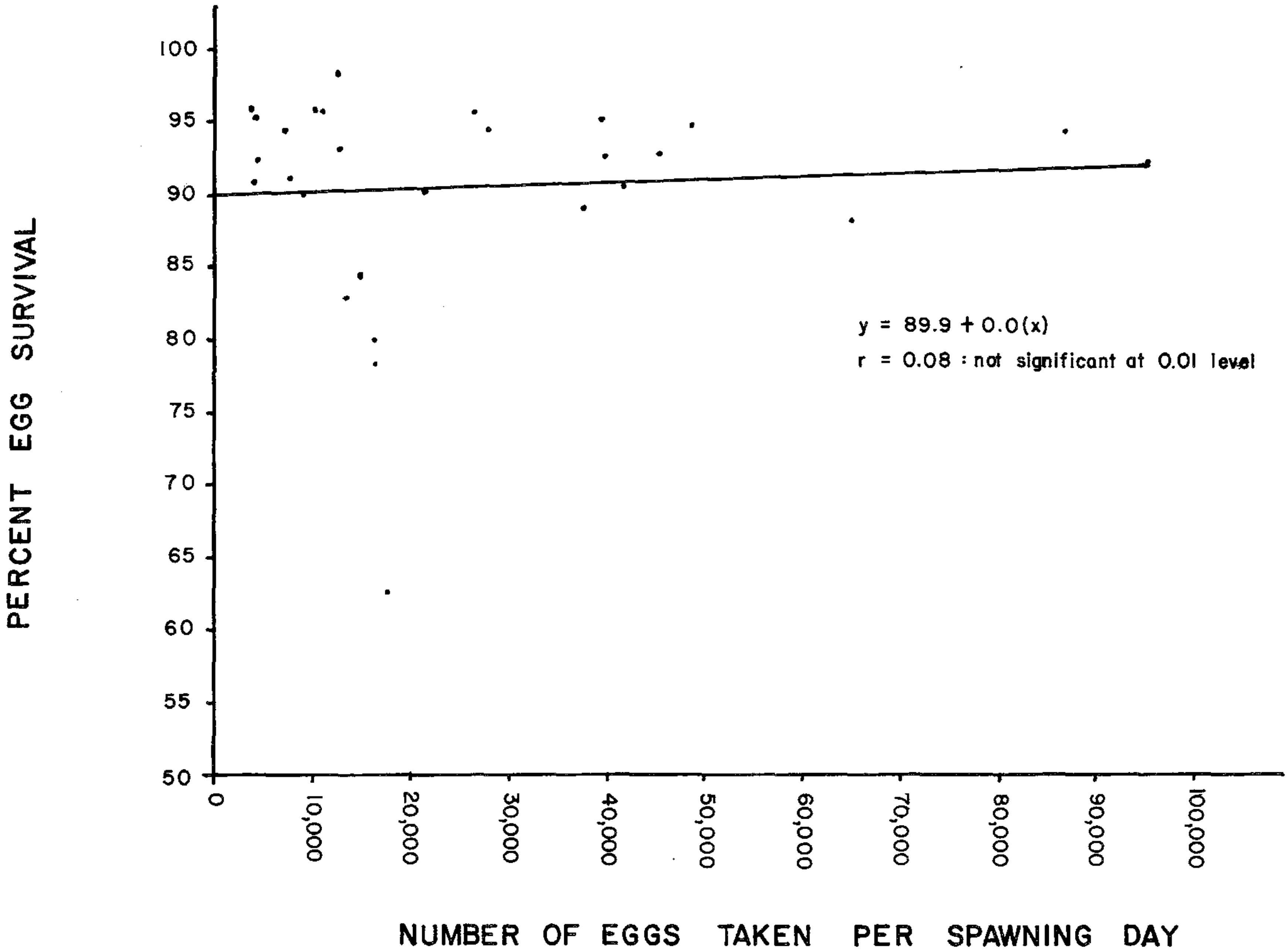


FIG. 7. SUMMER CHINOOK EGG SURVIVAL DURING INCUBATION RESULTING FROM TEMPERATURE AT TIME OF EGG TAKE: BROODS 1972 - 1976

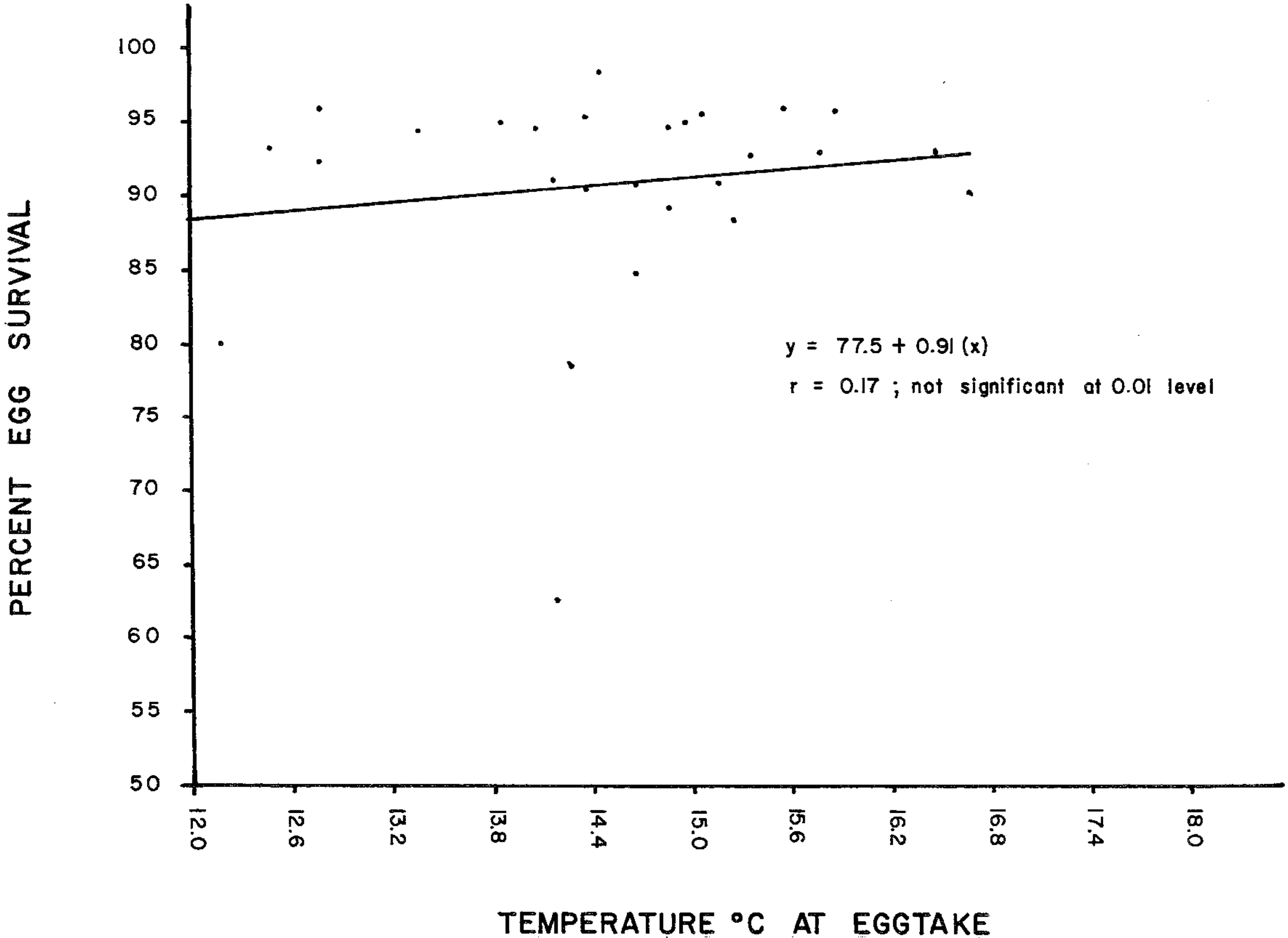


FIG. 8. SUMMER CHINOOK FRY SIZE AT PONDING (NUMBER / lb.) RESULTING FROM ADULT FEMALE SIZE AT SPAWNING: BROODS 1973 - 1976

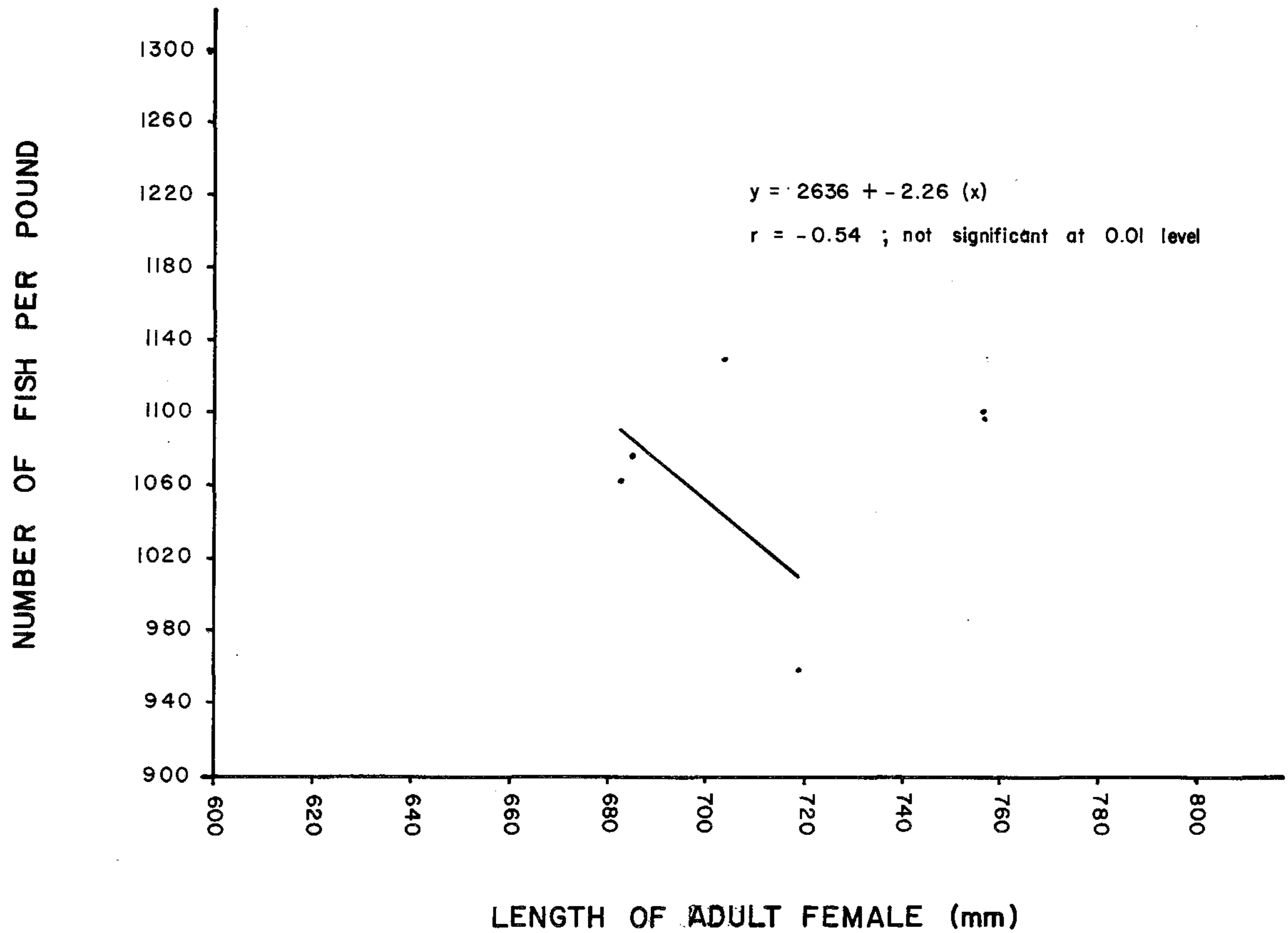


FIG. 9. LENGTH OF SUMMER CHINOOK DURING REARING (MM) VERSUS ACCUMULATED THERMAL UNITS (°C)

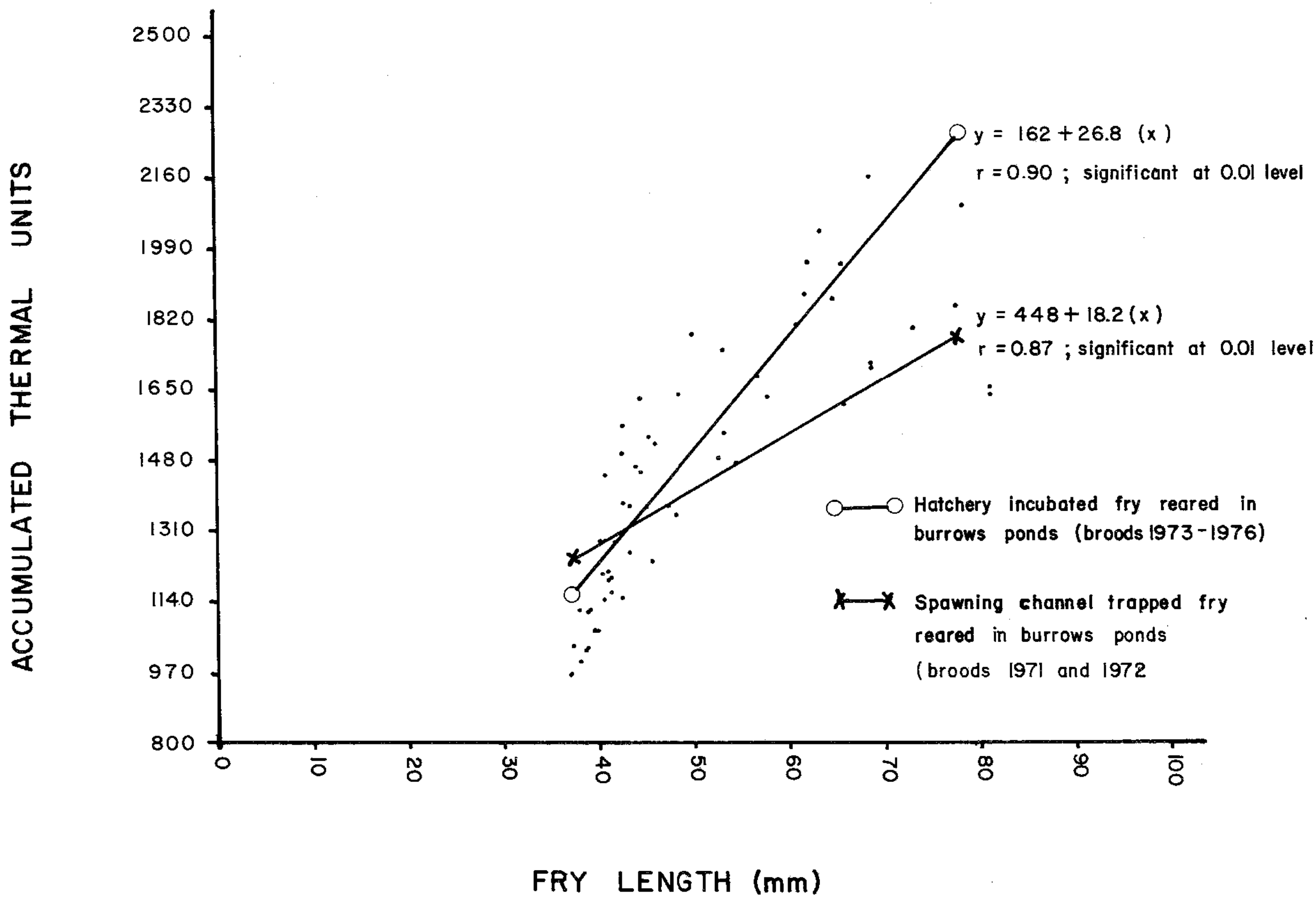


FIG. 10. LENGTH OF SUMMER CHINOOK (MM) DURING REARING VERSUS ACCUMULATED THERMAL UNITS (^{o}C)

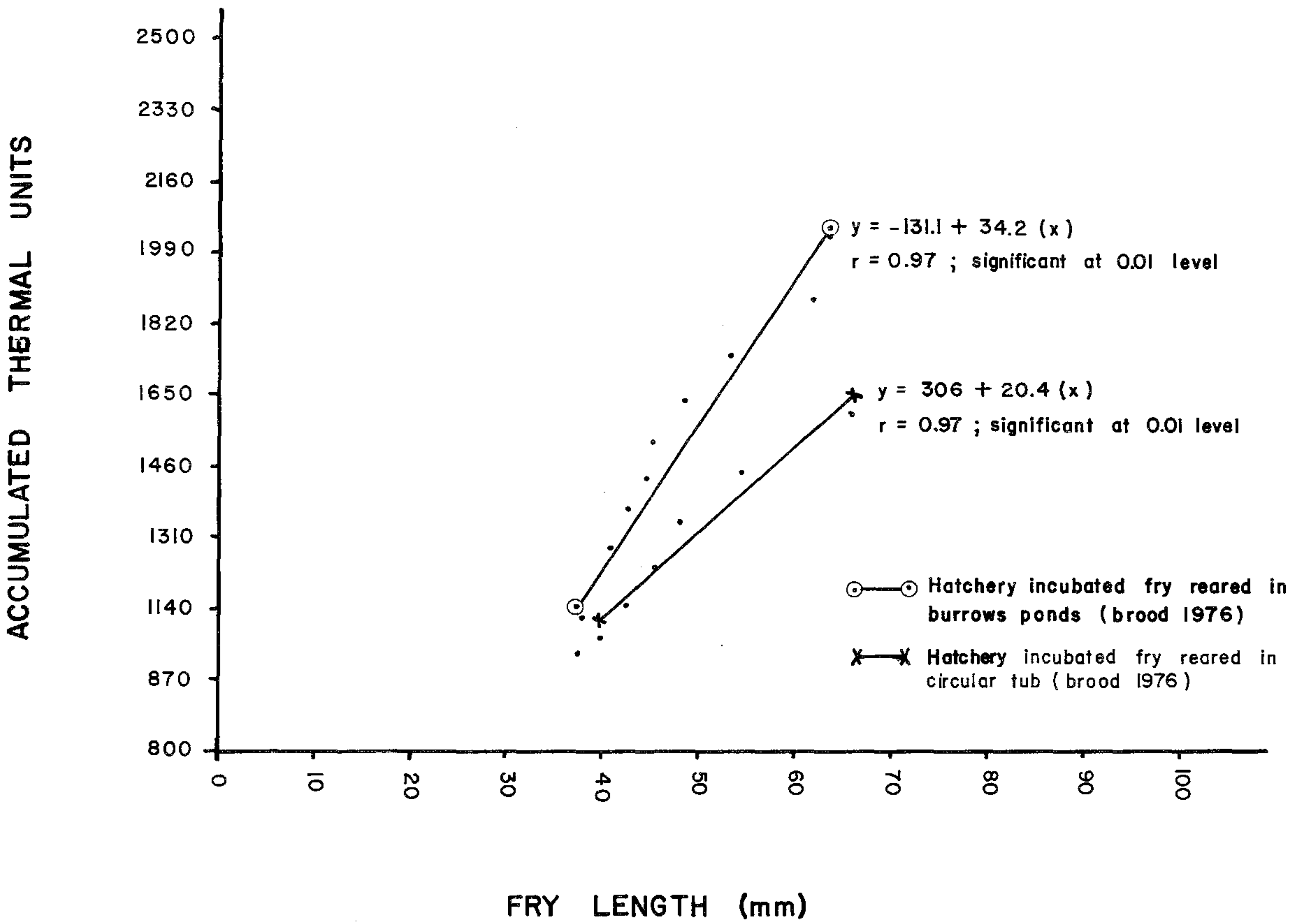


FIG. 11 LENGTH OF SUMMER CHINOOK SUPER SMOLTS (MM) DURING REARING VERSUS ACCUMULATED THERMAL UNITS (°C) : BROOD 1973

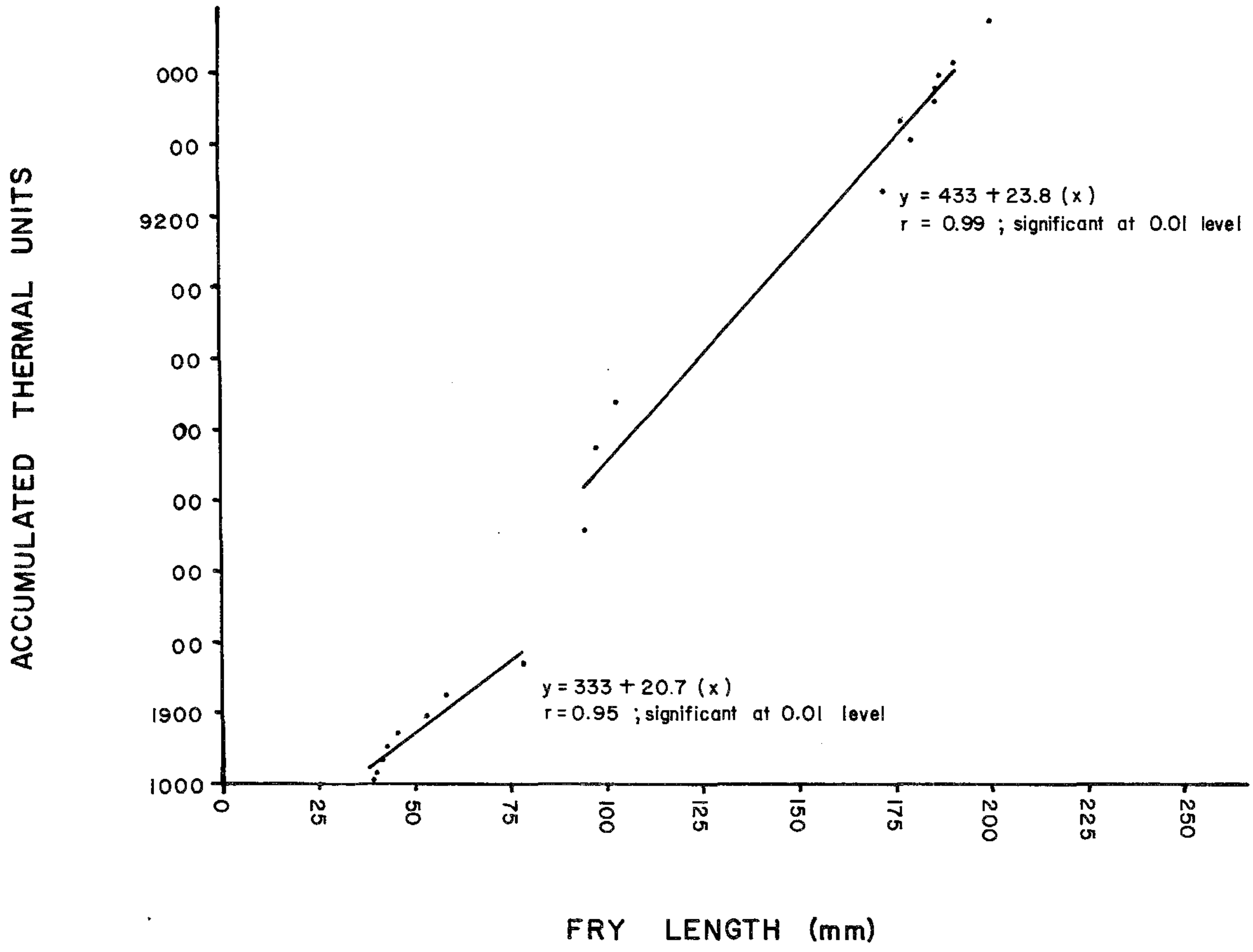


FIG. 12. CONDITION FACTOR (K) OF SUMMER CHINOOK VERSUS DAYS REARED: BROODS 1972 - 1976

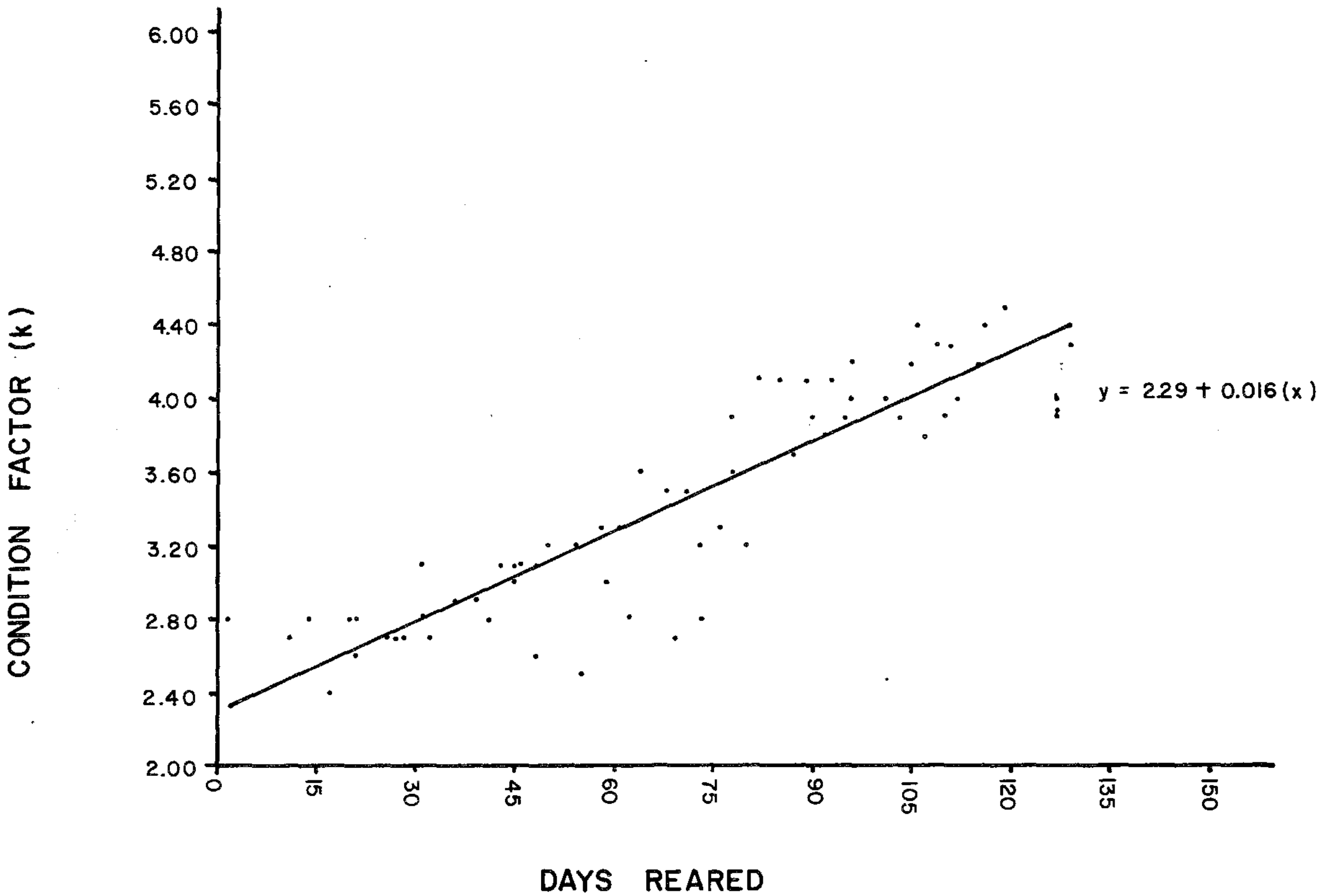


FIG. 13. PINHEAD REARING MORTALITY OF SUMMER CHINOOK (PERCENT AT SAMPLE) VERSUS ACCUMULATED THERMAL UNITS ($^{\circ}$ C) : BROODS 1972 - 1976

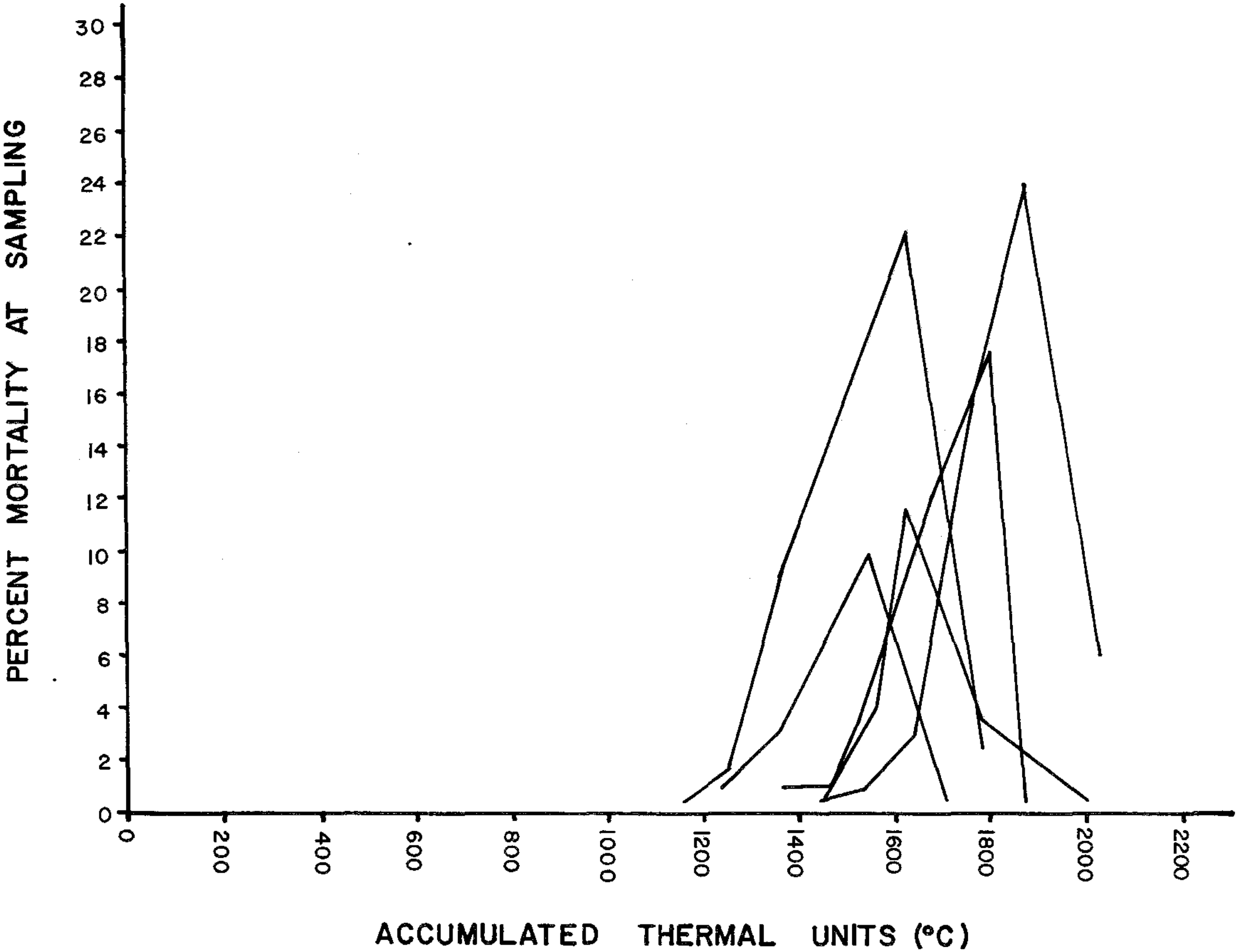
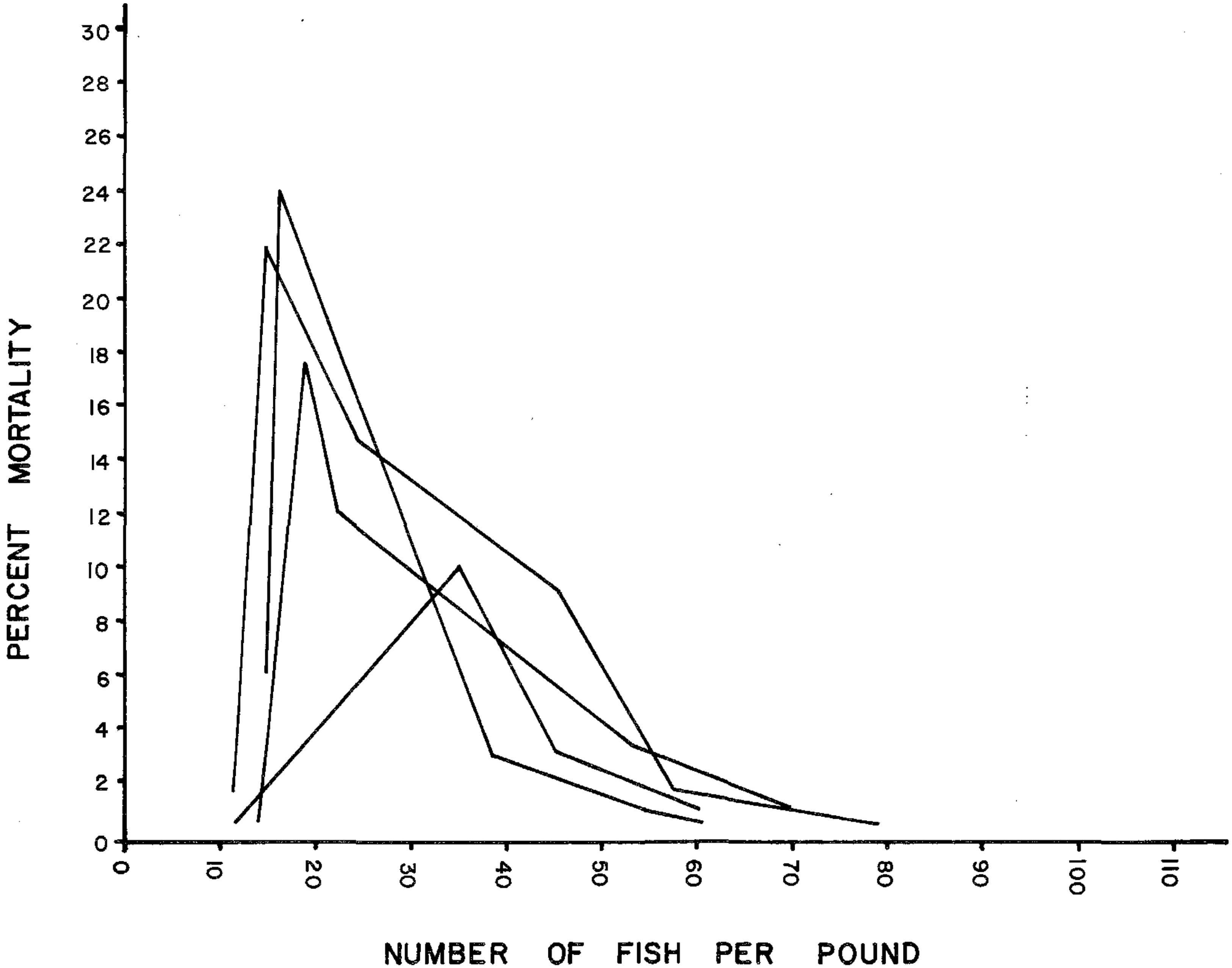


FIG. 14. PINHEAD REARING MORTALITY OF SUMMER CHINOOK (PERCENT AT SAMPLE) VERSUS NUMBERS OF FISH PER POUND : BROODS 1973 - 1976



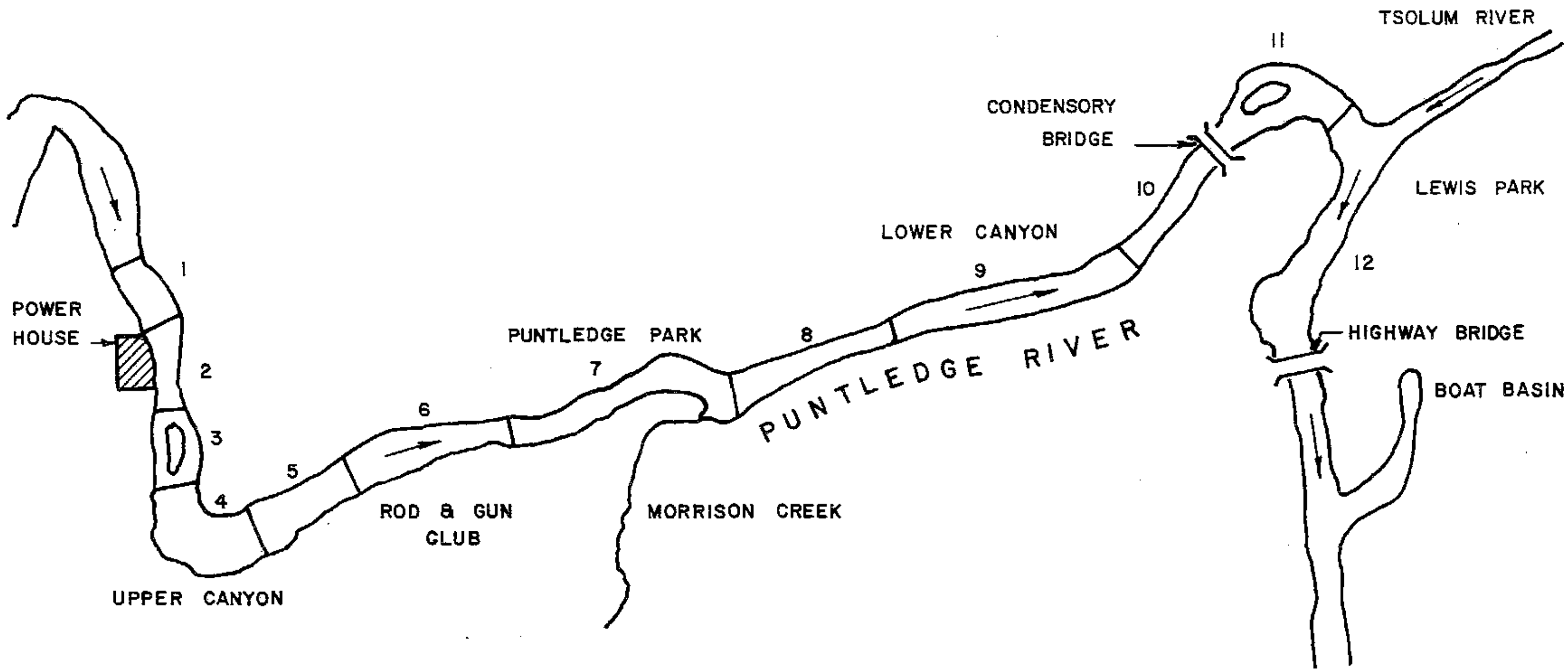


FIG. 15. DISTRIBUTION SECTIONS FOR ENUMERATION OF FALL CHINOOK (SEE TABLE 25)

FIG. 16 LENGTH OF FALL CHINOOK (MM) DURING REARING IN BURROWS POND VERSUS ACCUMULATED THERMAL UNITS : BROODS 1972 - 1975

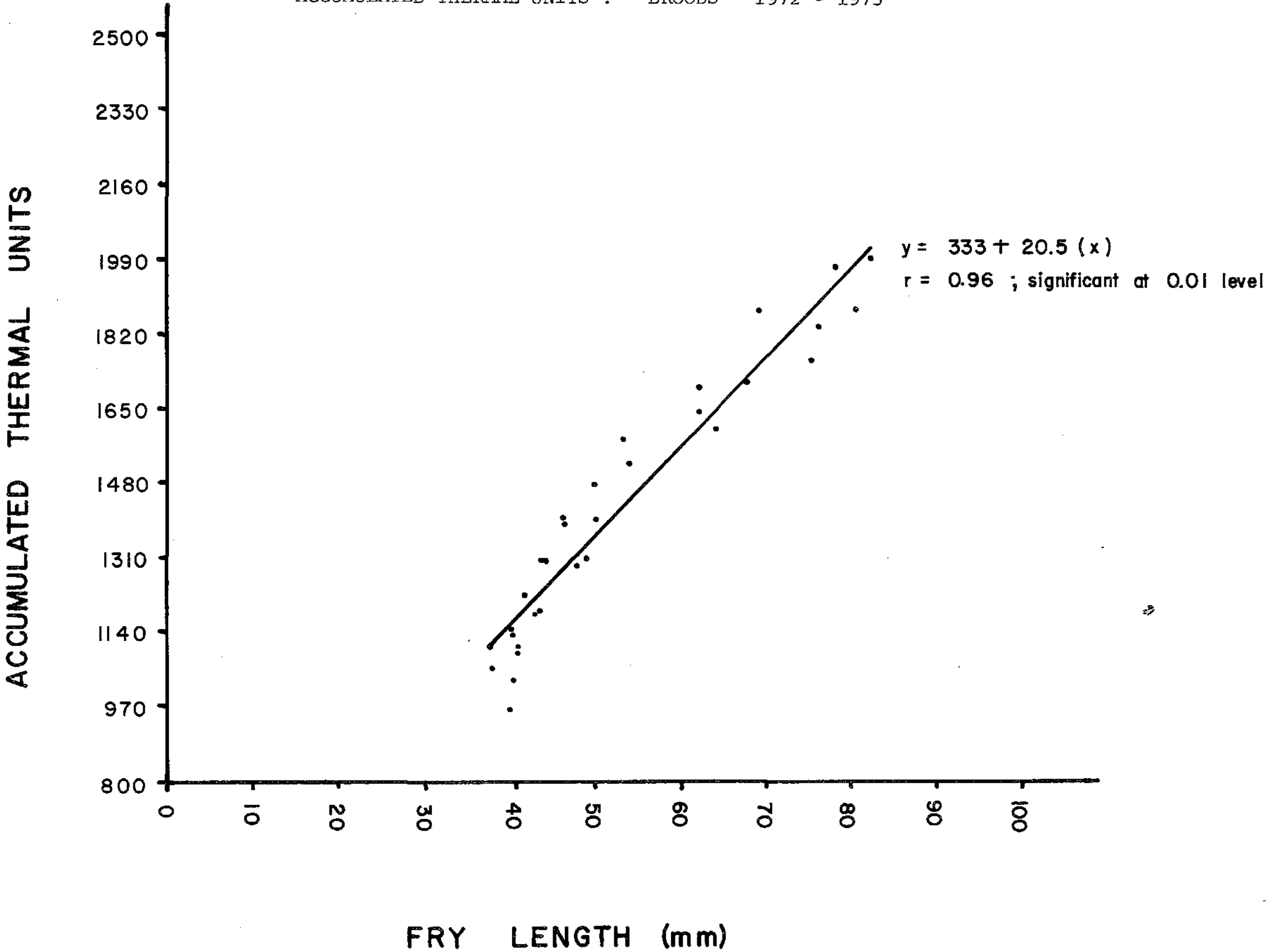


FIG. 17. LENGTH OF FALL CHINOOK (MM) DURING REARING IN CIRCULAR TUB VERSUS ACCUMULATED THERMAL UNITS : BROOD 1976

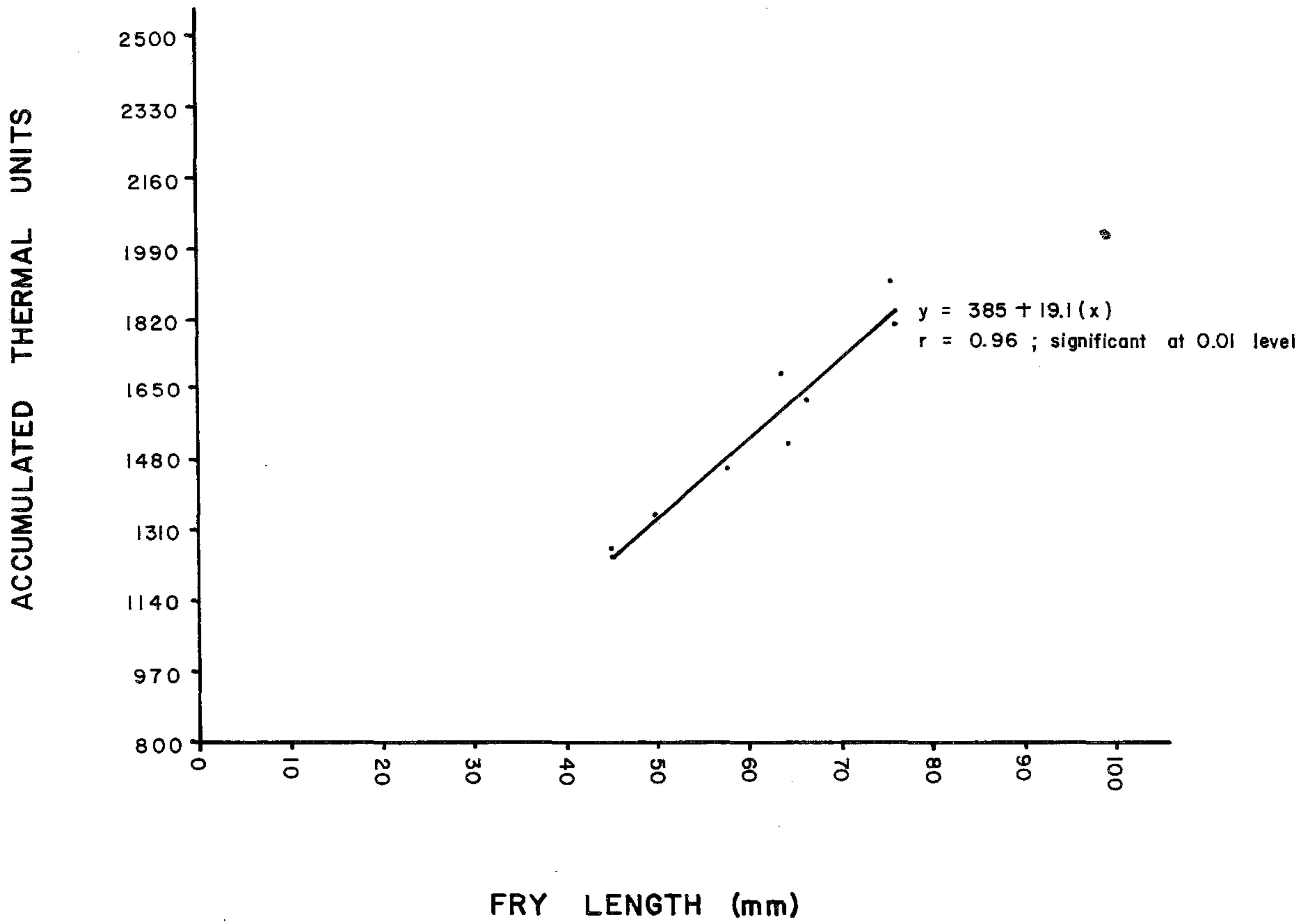


FIG. 18 CONDITION FACTOR (K) OF FALL CHINOOK VERSUS DAYS REARED : BROODS 1972 - 1976

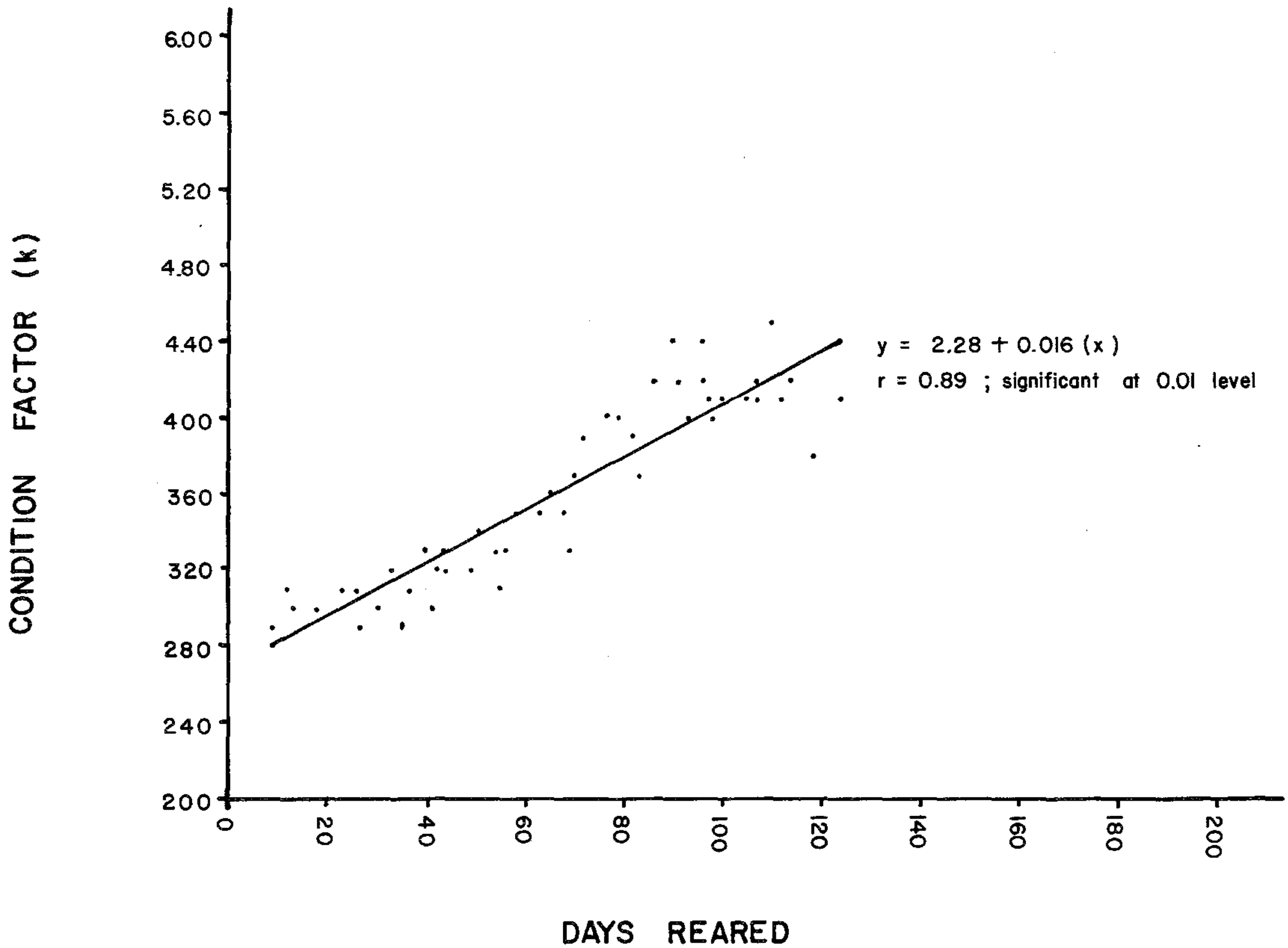
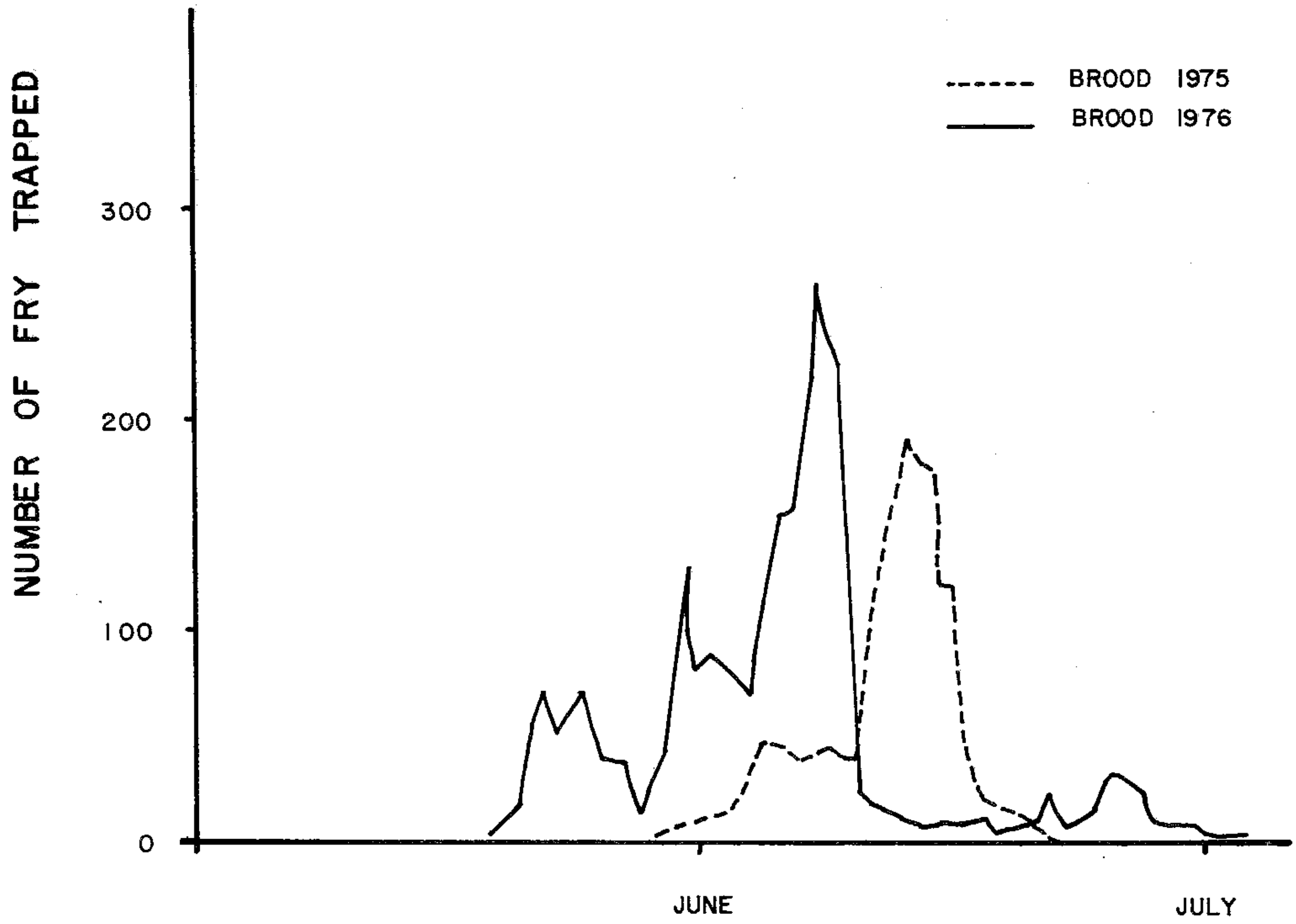


FIG. 19. TIMING OF STEELHEAD FRY EMIGRATION FROM SPAWNING CHANNEL
(TRAP CATCH COEFFICIENT = 4.53)



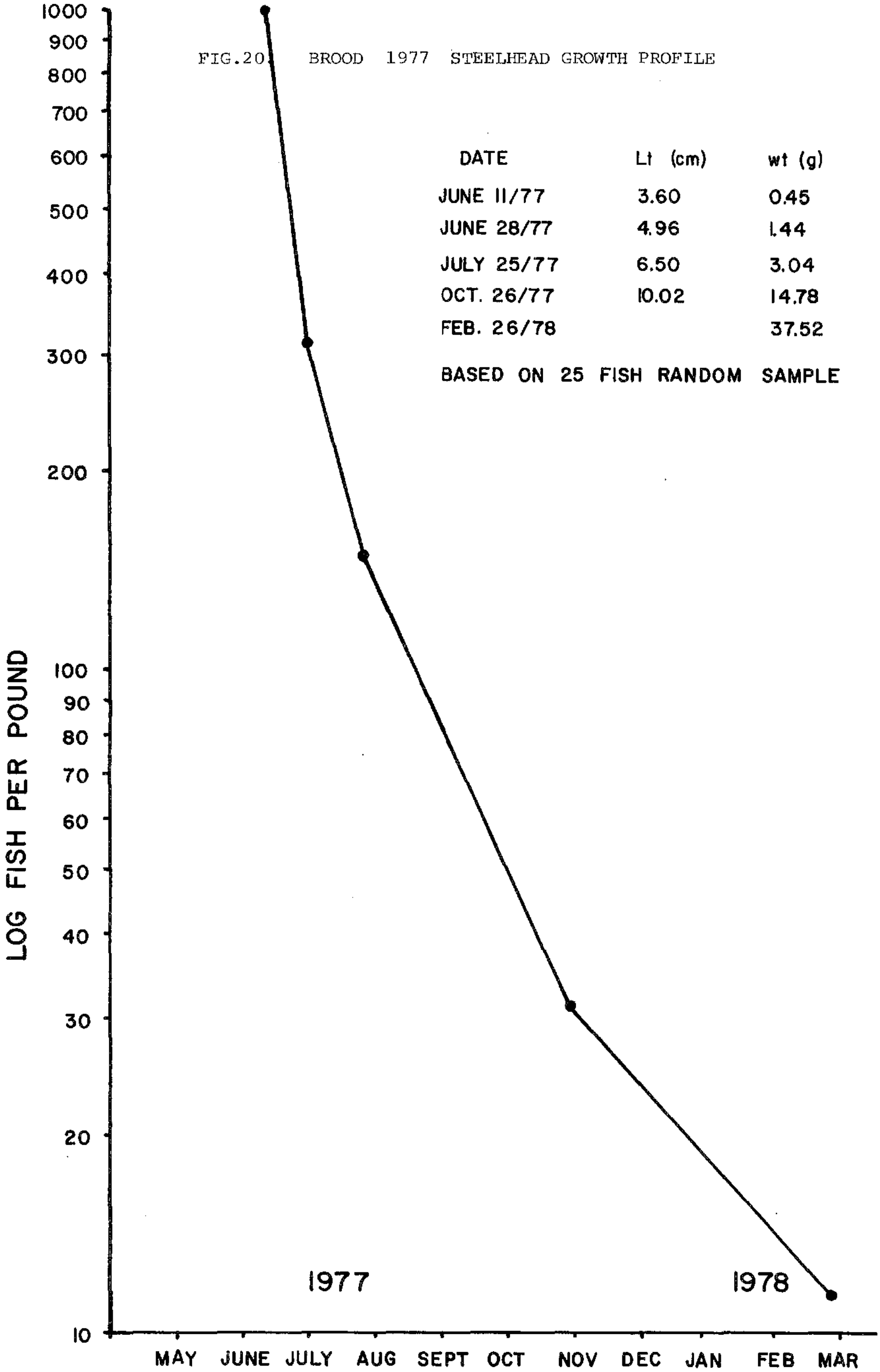


FIG.20. BROOD 1977 STEELHEAD GROWTH PROFILE

FIG. 21. MEAN TEMPERATURE OF PUNTLEDGE RIVER SPAWNING CHANNEL WATER 1966 - 1975