DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Marine Fisheries Service
Grant-in-Aid Program

PROJECT COMPLETION REPORT

State of Washington

Program: [X] 309 [ ] 304

Project Title: SKAGIT CHINOOK RACE DIFFERENTIATION STUDY

Project No: 1-98-R

Period Covered: July 1, 1974-June 30, 1975

Abstract:

SEE ATTACHED

(Text attached)

Date July 1976

Project Leader Russell Orrell

Title Fisheries Biologist

State of Washington
Department of Fisheries
115 General Administration Building
Olympia, Washington 98504

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INTRODUCTION

The Skagit River (Figure 1) is the largest river in the Puget Sound Basin (Figure 2). The Skagit River originates in British Columbia, flows in a southwesterly direction, and enters Ross Lake near the Canadian border. Ross Lake is formed by Ross Dam, the uppermost of three Seattle City Light Company hydroelectric dams on the mainstem Skagit River. Below Ross Dam the Skagit River flows through the reservoirs of Diablo and Gorge Dams. The free-flowing Skagit continues below the Gorge powerhouse at Newhalem, a distance of 94 river miles (RM) from its point of entry into Skagit Bay. Major tributaries entering the Skagit River below the Gorge powerhouse include the Cascade River at Marblemount, the Sauk River below Rockport, and the Baker River at Concrete. Puget Sound Power & Light Company operates two hydroelectric dams on the Baker River--Upper and Lower Baker dams. Lesser tributary streams of varying size enter the Skagit throughout its length.

All five species of Pacific Salmon (coho, Onorchynchus kisutch; chinook, O. tshawytscha; chum, O. keta; pink, O. gorbushca; sockeye, O. nerka) utilize the Skagit system for spawning and rearing and contribute to the catch. There are three distinct races of chinook--spring, summer, and fall. Chinook spawn in the 71-mile section of the mainstem Sauk River between Sedro Woolley and the Gorge powerhouse, in 40 miles of the Sauk River, and in 21 miles of the Cascade River. Additional chinook spawning occurs in larger tributary streams throughout the drainage. Pink salmon spawn in the mainstem Skagit, Sauk and Cascade Rivers and tributary streams. Coho salmon utilize nearly every accessible tributary stream, and also spawn in the mainstem Skagit, Sauk, and Cascade Rivers. Chum salmon utilize the mainstem Skagit and lower sections of the Sauk and Cascade Rivers and tributary streams. Sockeye salmon production is largely dependent on artificial spawning beaches located on the Baker River, though spawning also occurs in the lake and its tributaries when the run exceeds the capacity of the artificial beaches.

Spring Chinook

The Skagit River spring chinook run begins in April, peaks in mid-May, and ends during mid-June. Spring chinook migrate into the upper Sauk, Suiattle, and Cascade Rivers as much as 3 or 4 months prior to spawning. This race utilizes spawning grounds distinct from summer and fall chinook. Spring chinook spawn in the Sauk River from RM 21 to a falls at RM 41 on the North Fork and also utilize about 2 miles of the South Fork below another barrier to upstream migration. The

area between the Whitechuck River and the forks is the most heavily utilized. Spring chinook spawn in the Suiattle River primarily in tributary streams, including Big, Tenas, Buck, Downey, Sulphur, and Lime Creeks. Spring chinook spawning grounds in the Cascade River begin above a canyon at RM 8, and continue upstream to RM 5 on the North Fork and RM 20 on the South Fork. A total of 40 miles of spawning grounds is known to be utilized by spring chinook, including 22 miles of the Sauk River, 13 miles of the Cascade River, and 5 miles of Suiattle River tributaries. Because of glacial coloration, utilization of the mainstem Suiattle River for spring chinook spawning is unknown. It appears from carcass observations, however, that little spawning occurs in the main river.

Enumeration of spawning spring chinook is limited to index areas assumed to be representative of the total spawning area. Index areas include 7 miles of the upper Sauk River between the forks and the mouth of the Whitechuck River, and four Suiattle River tributaries: Big, Buck, Tenas, and Sulfur Creeks. Spawning ground surveys on the upper Sauk River are made by rubber raft, helicopter, and airplane, whereas foot surveys are made on Suiattle River tributaries. Spawning ground counts of spring chinook have been made since 1959 to determine adult abundance in all index areas. Because of the variability between the time of peak spawning for different years, each index area is surveyed a number of times to insure the peak is observed. Peak adult counts for index areas are expressed as the number of fish per mile, and total escapement estimates are based on a comparison of years for which index counts are available.

The first spring chinook spawning is in the Suiattle River tributaries as early as mid-July. Spawning in this area normally reaches a peak prior to mid-August and continues until mid-September. The first arrival of spring chinook on the spawning grounds coincides somewhat with flow conditions in the tributary streams, the first good counts being made after an increase in stream flows. Spring chinook spawning in the Sauk River upstream from Darrington begins in early August, reaches a peak in late August or early September, and is complete by mid-September. Surveys of spring chinook abundance in the upper Cascade River have been limited. Observations indicate that timing in the Cascade River coincides with other Skagit River spring chinook spawning areas.

Summer Chinook

Summer chinook salmaon begin entering the lower Skagit in mid-June, and continue until early August. Summer chinook may spend as long as 2 months maturing in the river prior to spawning. Summer chinook spawning grounds include 71

miles of the main Skagit River from Sedro Woolley to Gorge powerhouse, the Sauk River from its mouth to RM 21 at Darrington, and the lower 3 miles of the Cascade River. Spawning also occurs in larger tributary streams, including the Baker River, Illabot, Diobsud, Bacon, Falls, and Goodell Creeks. Summer chinook begin spawning in mid-August and continue until early October.

Fall Chinook

Fall chinook begin to enter Skagit Bay and the Skagit River in late July, overlapping with summer chinook. Migration into the river continues through August and September, with spawning beginning in late September and continuing through October. It appears that fall chinook spawning in the mainstem Skagit River is at least partially a result of juvenile chinook releases from Skagit Hatchery. Large numbers of fall chinook, originating from Green River Hatchery stock, have been released from Skagit Hatchery into the Skagit River since 1957 (Table 1). Furthermore, low hatchery returns suggest that straying occurs (Table 2).

Age Composition

Biological data (scales, length measurements, and sex determination) have been collected from chinook harvested in the Skagit Bay commercial fishery and carcasses recovered on the spawning grounds. Scales from spawning ground carcasses are used to determine freshwater age; because of absorption, however, these scales cannot be used to determine saltwater age. Therefore, age data from the commercial catch is used primarily to reflect age composition.

Four-year-old chinook are the major contributor to the gill net catch, and from 1965 to 1972 represented 73.4% (Table 3, Figure 3). The second largest year class was 5-year-olds (16.0%), followed by 3-year-olds (9.6%). Six-year-old fish comprised only 1.1% of the catch. Because of the large-mesh gill nets used for chinook, 2- and 3-year-old chinook are not harvested at a rate proportionate to numbers returning. Length frequency data obtained from seining near Hamilton showed that 27% of the chinook caught were less than 60 cm in length, the minimum size harvested by gill nets.

Chinook age cannot be determined by length. As shown by Figure 3, there is almost complete overlap between all age classes.

Commercial Harvest

Mature Skagit River chinook, along with British Columbia, Nooksack River, and Samish River stocks, have historically been harvested by commercial fisheries along West Beach (northwest side of Whidbey Island) and in Skagit Bay. In Skagit Bay, chinook of Skagit River origin are harvested by a variety of gear types. A portion of the bay lies within the boundary of the Swinomish Indian Reservation, and the Swinomish Tribe operates two fish traps south of Hope Island. Drag seines are also fished by Indians on the Swinomish Reservation; however, these are used primarily for the harvest of pink salmon during odd-numbered years, with chinook being captured incidentally. Indians fish on- and off-reservation with gill nets. The non-Indian harvets of chinook in Skagit Bay is limited almost entirely to gill net gear.

Wild and hatchery chinook have not been marked to determine migratory patterns and contribution to fisheries outside Skagit Bay and West Beach. If Skagit chinook can be assumed to behave in a manner similar to Puget Sound chinook stocks that have been marked, they contribute to catches of commercial and sport fisheries of Washington, British Columbia, Oregon, and Alaska.

There has been a continuing decline in the number of chinook harvested in Skagit Bay because of increased harvest of Skagit chinook by the "outside" fisheries and decreased production. Skagit Bay commercial catches for the 10-year period from 1935 to 1944 averaged 31,601 chinook annually (Table 4). The annual average catch dropped to 21,056 for 1945-1954 and to 15,501 and 11,900 for 1955-1964 and 1965-1972, respectively. The average for 1965-1972 was greatly increased by the 1965 catch of 27,278 and the 1966 catch of 19,180. Since 1967, catches exceeded 10,000 only during 1968 (10,816).

Although the annual Skagit Bay chinook catch has shown a sharp decline since 1967, the catch per landing (CPUE) for gill nets has increased. For the years 1955 through 1966 the CPUE was 4.3, while for the years 1967 through 1972 the CPUE was 6.1. The primary cause of the difference between the CPUE for these periods was the restrictive regulations necessary to protect summer chinook to assure adequate escapement.

The seasonal distribution of commercial Skagit Bay chinook catches has been altered since the mid-1960's because of the need to protect summer chinook stocks and allow an adequate escapement (Figures 4 and 5). The opening of Skagit Bay has been delayed until the end of July, with limited fishing time for the first 2 weeks, and a closure along West Beach to the 15-fm depth contour. These restrictions have resulted in a higher percentage of the chinook catch occurring after

August 1 when hatchery fall chinook begin entering Skagit Bay. The timing of the catch from 1935 to 1958 is typified by a bimodal curve with a depression near mid-August. Based on Samish-Bellingham Bay catches, hatchery fall chinook enter the fishery in the first week of August, the run peaks in mid-August, and is through the fishery by the second week of September. Catch distribution prior to 1958 shows that Skagit wild chinook stocks (summer) were in the Skagit Bay catch from May to mid-September and, furthermore, a substantial number were being caught after August 1, the period during which fall chinook would enter the catch.

Four-year-old fall chinook of hatchery origin first returned in 1961, and have continued through 1972. The period 1959-1966 thus includes 6 years of hatchery fall chinook returns and illustrates the impact of hatchery releases on Skagit Bay catches. During the period 1959-1966, the depression in the catch during mid-August was eliminated, probably because of catches of these hatchery fall chinook. The percentage return of hatchery fall chinook probably was not great in view of the large numbers released and the total chinook catch.

Skagit summer chinook first enter Skagit Bay in mid-June and continue through the bay until mid-September. That portion of the run entering the bay after August 1 overlaps the timing for hatchery fall chinook. Thus the summer run contains a segment which would enter the river during the same period of time as hatchery fall chinook.

OBJECTIVES

The 1973 Skagit Chinook Race Differentiation Study was comprised of two phases: adult and juvenile. Objectives of the adult study were to determine spawning distribution, abundance, and timing for summer and fall chinook, develop a method to provide separate escapement estimates for these races, and determine the impact of naturally spawning hatchery fall chinook on wild stocks. Spring chinook spawning grounds are distinctly separate from summer and fall chinook and already adequately surveyed. Therefore, more intensive surveys of spring chinook spawning grounds were not necessary. Objectives of the juvenile study were to determine spects of freshwater life history, growth and survival rates, effect of river flow fluctuations caused by releases from the dams, and fisheries contribution. Wild chinook fry were to have been coded-wire tagged to determine marine survival, migration patterns, and rate of contribution to the various fisheries.

ADULT STUDIES

Methods

Adult chinook were tagged in the Skagit River near Hamilton during the 1973 pink salmon seining program. All chinook in good condition were tagged with disc tags and streamers and released at the site. Seining began on August 20, and 13 chinook were tagged with a combination of red disc and green flag. On August 27, 28, and 31, a total of 35 chinook were tagged with a yellow disc and yellow flag. A total of 72 chinook were tagged on September 4-7 with a white-white combination, and 32 chinook were tagged with a green-white combination on September 10 and 11. In addition, 52 chinook were tagged green-yellow on September 11-13. A total of 64 females, 139 males, and 1 sex unknown were marked and released. Tagged chinook were recovered and observed during spawning ground surveys made by foot and boat on the Skagit River and its tributaries and at Skagit Hatchery.

Distribution, time of spawning, and separation of summer and fall chinook stocks were determined by aerial surveys. Aerial surveys of the Skagit River had previously been made by fixed-wing aircraft; during 1973, however, surveys were made by boat and helicopter in addition to fixed-wing aircraft. It was felt that because of the slower flying capability of a helicopter and improved visibility, more accurate redd counts could be obtained. Fixed-wing aircraft were used to compare counts made by the two methods. Surveys by helicopter and fixed-wing aircraft were made as close together as possible on the Skagit River from the mouth of the Sauk River to Newhalem, and on the Sauk River from the mouth of the Suiattle River to Darrington. Because of poor visibility from glacial runoff from the Suiattle River drainage, surveys could not be made on the Skagit River below the mouth of the Sauk or on the Sauk River below the mouth of the Suiattle.

Surveys were made when water and light conditions were optimum for redds to show distinctly. Chinook excavate a relatively large area prior to egg deposition and algae growth is removed. For a period of time following excavation, redds can be observed easily, and these distinct redds were counted. Redds under construction or old redds visibile due to a tailspill were not included.

Aerial surveys began on September 1 and continued until October 18, and a total of five helicopter and four fixed-wing flights were made on the Skagit and Sauk Rivers. Helicopter surveys of the Skagit River were made on September 1, 8, and 20 and October 1 and 18; helicopter surveys of the Sauk River were made on the same dates except September 20. Dates of fixed-wing aircraft surveys were September 5, 18, and 28 and October 8 for both rivers. Redd counts were made by flying either upstream or downstream, depending on the location of the sun, to minimize reflection off the water. Helicopter air speed varied from 0 to 35

miles per hour depending on redd density. Air speed of the fixed-wing aircraft was relatively constant, varying from 70 to 80 miles per hour, depending on direction and speed of wind. In sections of high redd density it was necessary to circle to obtain an accurate redd count.

Skagit River chinook redd counts in the 27-mile section from the mouth of the Sauk to the Gorge powerhouse were separated into two sections during the surveys on September 1, 8, and 20. During these surveys, redds were counted in the Sauk to Cascade and Cascade to Gorge powerhouse sections. Redd counts were made in five sections of the Skagit River during surveys made on October 1 and 18. The five sections were the Sauk River to Cascade River, Cascade River to Diobsud Creek, Diobsud Creek to Bacon Creek, Bacon Creek to County Line Ponds, and County Line Ponds to the Gorge powerhouse. Sauk River redd counts were made in the 7.8-mile section between the mouth of the Suiattle River and the bridge at Darrington.

Spawning ground surveys were made on the Skagit and its tributaries to collect tags and obtain biological data. All chinook carcasses which could be recovered were sexed, measured for length, and scale sampled. Females were further examined to determine egg retention.

Results

Survey method comparison

Helicopter and fixed-wing surveys were made during 1973 to determine which method produces the most accurate redd counts. Fixed-wing surveys were required for comparison with fixed-wing surveys for 1952-1972. Three surveys were made on nearly the same date, and the redd counts can be used to determine the difference between helicopter and fixed-wing counts. Because surveys were not made on identical dates, a curve was drawn showing the daily number of redds. visibile by helicopter. Fixed-wing aircraft counts for September 5, 18, and 28 were 68% of the estimated number of redds which would have been counted by helicopter (Table 5). Surveys by fixed-wing aircraft on the Sauk River on September 5 and by helicopter on September 1 and 8 showed a similar discrepancy. The fixed-wing count for September 8 (325) was 41% of the estimated helicopter count (790).

Large numbers of pink salmon spawn in the Skagit River during odd-numbered years and utilize the same river sections used by chinook. Although pink salmon prefer a somewhat different spawning habitat, generally mass spawn, and construct smaller redds, in areas where spawning overlaps it is necessary during observations to differentiate between redds of the two species. A distinct advantage of

helicopter surveys was the ability to stop and carefully observe redds.

Because helicopter counts were higher, they are considered more accurate, and the results of 1973 aerial surveys are based entirely upon helicopter surveys.

Skagit River timing of spawning

Helicopter redd counts for the Sauk to Cascade and Cascade to Gorge powerhouse sections are shown in Table 6. These daily redd counts were plotted on a graph and from these graphs the number of redds constructed each day was determined for each river section. In order to determine daily redd construction from aerial redd counts, it is necessary to know or assume redd life, the average number of days a redd is visibile. No data on chinook redd life were available from the literature; therefore, a redd life of 21 days was estimated from past experience. Daily redd construction was estimated by the following technique:

1. Observed redd counts were plotted on a graph, and a curve fitted to the counts.
2. Daily redd counts for each day of the spawning period were estimated from the graph.
3. The number of redds constructed the first day of spawning (day 1) is equal to the number visible on that day.
4. The daily number of redds constructed for days 2 through 21 was determined by subtracting the number of redds visible on the previous day from the number visible on the day in question.
5. After day 21 the daily number of redds constructed was determined for each day by adding the cumulative daily total redd count made 21 days before that day to that day's number of visible redds. The number of redds constructed that day was determined by subtracting the previous day's cumulative total from that day's cumulative total.

The first Skagit River aerial survey was made on September 1; 545 redds were counted between the mouth of the Sauk River and the Cascade River. Based on this count and/or past observations, it was estimated that redds would have first been visible on August 16. Redd counts for each survey were plotted on a graph and a curve fitted to the redd counts (Figure 6). The number of redds constructed each day (Table 7) was determined in the manner previously described. The redd construction data show a bimodal curve (Figure 7), with the two peaks of red construction occurring on September 8 and 29. Burner (1951) observed that female

chinook may spend as many as 5 days of pre-spawning redd construction activity. Based on this observation, the two peaks of spawning in the Sauk to Cascade section occurred on September 13 and October 2.

Redd counts for the Cascade to Gorge powerhouse section indicated timing similar to the Sauk to Cascade section (August 15 to October 30)(Figure 8, Table 9). Daily redd construction estimates show a bimodal distribution with peaks occurring on September 14 and October 6 (Figure 8). Based on Burner's observation, the two dates of peak spawning occurred on September 19 and October 11.

Sauk River timing of spawning

Aerial counts of chinook in the Sauk River from Suiattle to Darrington began on September 1 and ended on October 18 (Table 6). Based on these surveys, it was estimated that redds would have first been visible on August 16 and the last redds visible on October 19. The number of redds constructed daily (Figure 10, Table 9) was determined by the same technique used for the Skagit. Redd construction data for the Sauk River show a bimodal distribution with a major peak occurring on September 3 and a minor peak on September 25 (Figure 11). Based on Burner's observations, the two peaks of spawning occurred on September 8 and 30. The major portion of spawning occurred during the segment which peaked on September 8 and occurred primarily prior to September 21. Abundance of redds in early October was relatively minor, the Sauk River primarily serving as a spawning area for the early segment of the summer chinook run.

Sex ratio

Spawning ground surveys were made by foot and boat on the Skagit River and tributary streams to recover tagged chinook and determine the ratio of females to males. Additional sex ratio data were obtained during chinook tagging near Hamilton. The sex ratio obtained from spawning ground surveys diverged greatly from that observed during tagging. Carcasses recovered during surveys included 155 females and 102 males, a ratio of 1.51 females per male. On the other hand, during tagging, 139 males and 64 females were observed, a ratio of 1 female to 2.17 males. This is explained by examination of length frequencies for both sexes from chinook recovered during surveys and tagging. Spawning ground carcass length frequencies show an almost complete absence of males less than 70 cm whereas they were abundant in the tagging study.(Figure 12). Carcasses of small males are more difficult to observe and more easily preyed upon. The sex ratio observed during tagging is assumed to be the most accurate data.

Retained eggs

A total of 168 female chinook was examined for retained eggs (Table 10); 89.3% had from 0 to 24 eggs remaining, 7.7% had from 25 to 99 eggs, 1.7% had 100 to 499 eggs, and 1.2% had from 500 to 999 eggs. No female retained over 1,000 eggs. These samples indicate that egg retention was not significant during 1973.

Distribution and Abundance

Distribution of spawners can be based on the number of redds observed in each of the two river sections. However, data must be obtained regarding number of fish per redd and occurrence of false redds before the number of redds can be used to accurately determine the number of fish in the escapement. The Sauk to Cascade section, which is 10.8 miles in length, had a total of 1,860 redds, or 172.2 redds per mile. Between the Cascade and Gorge powerhouse there was a total of 2,635 redds in 16.2 miles of river, or 162.7 redds per mile. In the 27.0 miles of index area there were 166.5 redds per mile. Chinook spawning was thus fairly uniform between the two river sections.

Redd counts in the 27-mile index areas were taken in five sections during surveys on October 1 and 18. The total count of 2,072 redds on October 1 was lower than the peak count made on September 20 (2,520), but enough redds were present to determine distribution in the five sections. On October 1, the number of redds per mile varied from 129.4 for the Diobsud Creek to Bacon Creek section section to 30.8 for the Bacon Creek to County Line section (Table 11). The low count for the Bacon Creek to County Line section is largely due to a gorge within the section that is unsuitable for spawning. Only 727 redds were observed on October 18.

Surveys in the Sauk River during 1973 showed that were 1,512 chinook redds in the 8.0 miles between the Suiattle and Darrington, or 189.0 redds per mile. Spawning density was somewhat higher in the Sauk River than in the Skagit River.

Impact of hatchery fall chinook

Skagit Hatchery fall chinook egg-take records (Table 12) for 1973 were examined to estimate the timing of redd construction for hatchery fall chinook. To determine when hatchery fall chinook redds would have been visible, 5 days were subtracted from the first date eggs were taken. It was estimated that the first hatchery fall chinook redds would have been constructed on September 7 and the last redds constructed on October 25. Based on aerial redd counts, the first redds constructed in the Sauk to Gorge section would have been on August 16 and

the last on October 12. Hatchery fall chinook spawning coincides with the last segment of the bimodal curve (Figure 13).

Tagging study

The number of chinook tagged at Hamilton (204) and the small number of recoveries (12) can only be used to show timing of wild and hatchery chinook stocks as they pass through this section of the Skagit (Table 13). A total of 120 chinook was tagged between August 20 and September 7, and four tags (3.3%) were recovered, all from the main river. Between September 10 and 13, a total of 84 chinook was tagged and 8 (9.5%) were recovered, five at Skagit Hatchery, one in Bacon Creek, one in Day Creek Slough, and one from the Baker River trap. It appears that hatchery and wild chinook are mixed as they pass through the lower Skagit.

Escapement enumeration

Foot surveys of spring chinook spawning grounds have been made annually since 1959. Counts of live and dead chinook are made on four Suiattle River tributaries: Big, Buck, Tenas, and Sulphur Creeks (Table 14). In addition, the 7.8-mile section of the Sauk River between the forks and the mouth of the Whitechuck River is surveyed by boat and by foot (Table 15). Each index stream is surveyed several times annually to obtain a count at or near peak of spawning. Surveys of Suiattle River index streams begin as early as the last week of July and continue into early September. Spawning in the upper Sauk River index area is later and surveys begin in late August. Two or three surveys are usually made by late September. Peak fish-per-mile counts from index streams are used to determine annual escapement levels. Counts from 1959 to 1972 show that spring chinook escapement have fluctuated, with the greatest fluctuation occurring in the upper Sauk River. Counts in Suiattle River tributaries have been relatively consistent.

Aerial redd counts have been made since 1952 to determine annual Skagit River summer chinook escapement levels. Counts have been made by fixed-wing aircraft in a 27-mile section between the Gorge powerhouse and the mouth of the Sauk River. Surveys are made near mid-day when light conditions are optimum and visibility is good. Observers count redds as the airplane flies along the river at a slow rate of speed (70 mph). When the redd density is low, redds may be counted individually. When densities are high, however, the number of redds must

be estimated. Even during years of low redd counts, estimates have to be made in the more heavily utilized spawning areas. Because all observers count in the same manner, the errors in redd counts resulting from estimating should be consistent from year to year. The number of fish per mile is determined for each survey by multiplying the total redd count for the 27-mile index area by a factor of 5 and then dividing by 27. Escapement levels are shown by a comparison of annual fish-per-mile counts.

From 1952 to 1972 the annual Skagit River index area fish-per-mile counts have ranged from 97 to 628 and averaged 253, Chinook spawning escapement, expressed as fish per mile, have been examined for use in predicting adult returns. However, no correlation was found between peak fish per mile counts in the index area and total adult returns 4 years later (Figure 14). Increased knowledge of the timing, distribution, and abundance of Skagit River chinook stocks is essential for good harvest management.

Discussion

Aerial redd counts on the Skagit and Sauk Rivers showed that fixed-wing aircraft counts were substantially lower than counts made by helicopter. The ability of a helicopter to fly at a slower rate of speed and to hover and the better visibility from the helicopter resulted in higher, more accurate redd counts. Because helicopter charters cost 7 to 8 times that of fixed-wing aircraft (two place), surveys during the early and late spawning periods (when redd densities are low) can be made by fixed-wing. However, during the period of peak redd abundance, surveys should be made by helicopter.

The method used to determine the total number of redds within a given river section can be refined by more accurately determining redd life, which will also more accurately determine timing. Furthermore, determining the frequency of false redds and redd life will make it possible to convert redd counts to numbers of fish. Redd counts for 1973 showed that peak spawning in the Sauk to Cascade section of the Skagit River was about 1 week earlier than the Cascade to Gorge section for both the late and early spawning segments. The beginning and end of spawning can be further defined by aerial surveys in late August and late October which will result in a more accurate estimate of total redds. Time of spawning in the Sauk River coincided with Skagit River timing for the early run segment; the late segment was of minor importance in the Sauk River. Because of poor visibility, redd counts were not obtained from the Sauk River below the Suiattle River and the Skagit River below the Sauk River. Chinook

spawning occurs in these river sections, but the timing and abundance of chinook cannot be determined for the 1973 brood year.

Results of female chinook egg retention sampling showed 97.0% retained less than 99 eggs. Egg retention was not considered significant during 1973.

Chinook spawning density, based on the number of redds per mile, was about equal between the two sections of the Skagit River above the Sauk River. Within the Cascade to Gorge section, the number of redds per mile varied for each of four sections. Redd counts were highest in the two sections between the Cascade River and Bacon Creek. The lowest redd count was in the Bacon Creek to County Line section, which included a gorge area not suitable for spawning. Chinook spawned in all suitable areas above the Sauk River during 1975, though redd density varied between individual spawning areas.

Time of spawning of hatchery fall chinook coincided with spawning of the late segment of wild chinook. There appears to be a potential for mixing of spawners from these stocks; the low rate of returns to the hatchery suggests the number of hatchery fall chinook spawning naturally in the Skagit River would be small in comparison to wild stocks. Naturally spawning hatchery chinook would be expected to spawn in the Marblemount area of the Skagit River and the lower Cascade River. Spawning ground surveys in 1974 should include river sections that would show distribution and abundance of the late segment of the run in these areas.

The small number of chinook tagged (20) and low number of recoveries (12) preclude all but the general conclusion that hatchery and wild stocks are mixed as they pass the Hamilton area during late August and early September.

JUVENILE STUDIES

Methods and Materials

Juvenile chinook sampling began on March 4 and continued until May 22 in the Skagit, Sauk, and Suiattle Rivers. During the 81-day period, a total of 21 days was spent collecting juvenile chinook from RM 0 to 87.5 on the Skagit, RM 0 to 32 on the Sauk, and at RM 8.0 on the Suiattle (Figure 2).

Samples were collected with a 100- x 6-ft beach seine (1/4-inch mesh) which was set by a 16-ft Valco river boat powered by a 70-hp jet-pump outboard engine. Also used was a backpack, battery-powered, Smith-Root Mark V electrofishing unit. During March, samples were collected primarily with the electrofishing unit because juvenile chinook are found in locations not suitable for seining during this period.

Captured fish were anesthetized with MS-222, measured to the nearest millimeter, and allowed to recover prior to release. Mean lengths were computed for each sample to estimate size and growth. Samples were also grouped and averaged on a weekly basis to determine growth rate.

Chinook fry were counted, weighed, and measured to determine fry condition in the upper Skagit River (County Line), Skagit River near Hamilton, Sauk River below Clear Creek, Sauk River below the Suiattle River, and from the Suiattle River. Samples were collected on March 27, April 18, and May 20 from these locations, and each was put on ice and taken to the lab for length and weight measurements. Fry were separted into 5-mm size groups for condition factor analysis, and each group weighed to the nearest 0.10 of a gram on an Ohaus model 700 triple beam balance. Excess moisture was removed from the surface of the fry before weighing. Condition factors for each group were determined by applying the following formula:

$$CF = \frac{W \times 10^5}{L^3}$$

where

CF = condition factor
W = mean weight of size group in grams
L = mean length of size group in millimeters.

Results

The results of the 3-month sampling program are summarized in Tables 1618, showing dates sampled, location, weekly groupings, days between weekly groupings, and mean length per weekly grouping. Table 19 shows the mean lengths by weekly groupings for spawning and non-spawning areas. Chinook mean lengths for weekly groupings for spawning and non-spawning areas are shown in Figure 15, and Figure 16 illustrates a growth curve.

Condition factors for chinook are shown in Table 20. The condition factors for each sampling site and individual size groups were compared statistically by analysis of variance, random block design. Results of analysis of variance are shown in Table 21.

Discussion

Juvenile chinook length data show that chinook fry were emerging throughout the March 4 to May 22 sampling period. The continual recruitment of newly emerged fry and migration of fry of all sizes into the lower river make evaluation of

growth rate difficult. The growth curve shown by Figure 15 indicates a slow growth rate and a trend towards movement of larger fry into the lower river. Within the non-spawning area of the lower river, chinook reached the 50-mm minimum length for micro-tagging about May 10, whereas in non-spawning areas, mean length was less than 46 mm on May 20.

Electrofishing gear was most successful for collecting fry in the upper Skagit, Sauk, and Suiattle Rivers. The number of fish caught per day and the small size precluded tagging. Seining was relatively unsuccessful in the upper river, the fry inhabiting protected areas not suitable for seining. The river section below Hamilton offers many ideal seining sites, and catches were substantially higher in this area. Catches in the North and South Forks were good, but seining was difficult because of limited seine sites, reduced fishing time caused by tidal fluctuation, and problems associated with seining over a sandy river bottom.

A portable microtagging station had been set up prior to sampling for tagging at various locations on the Skagit, Sauk, and Suiattle Rivers. Though large numbers of fish were caught, the number of fish over 50 mm in length was insufficient to justify tagging. Microtagging head molds for chinook less than 50 mm will have to be developed before a successful tagging program can be conducted. This study shows that when equipment is developed so smaller fish can be tagged, the most suitable river section for fish collection is the lower Skagit below Hamilton.

Condition factor analysis of variance for chinook fry collected at five sites on the Skagit, Sauk, and Suiattle Rivers showed the following:

1. CF differs between size groups and classes.
2. There is no significant difference in CF based on sampling locations.
3. It appears that time and location interaction, with the May sample included, contribute to significant differences in CF values. This is likely a result of growth and environmental conditions.

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Table 5. Comparison of redd counts by helicopter and fixed-wing surveys of the Skagit River and Sauk River index areas, 1973.

Area	Date	Redd count		Helicopter/ fixed-wing
		Helicopter	Fixed-wing	
Skagit River	Sept. 5	523	965	0.54
	Sept. 18	1,782	2,290	0.78
	Sept. 28	1,572	2,380	0.66
Total		3,877	5,635	0.69
Sauk River	Sept. 5	790[1/]	325	0.41

[1/] Redd count for this day was estimated by interpolating from counts on September 1 and 8.

Table 6 . Skagit and Sauk River redd counts by helicopter, 1973.

Section	Sept. 1	Sept. 8	Sept. 20	Oct. 1	Oct. 18
	No. of redds	No. of redds	No. of redds	No. of redds	No. of redds
Skagit River					
Sauk to Cascade	223	522	916	997	343
Cascade to Gorge	416	713	1,604	1,075	385
Total	639	1,235	2,520	2,072	728
Sauk River					
Suiattle to Darrington	545	973	NS	380	17

Table 7. Estimated daily number of redds visible and redds constructed in the Skagit River (Sauk to Cascade) in 1973 based on helicopter surveys.

Date		No. redds visible	Cumulative total redds	New redds
August	15	0	0	0
	16	12	12	12
	17	25	25	13
	18	35	35	10
	19	45	45	10
	20	55	55	10
	21	65	65	10
	22	80	80	15
	23	90	90	10
	24	100	100	10
	25	115	115	15
	26	130	130	15
	27	145	145	15
	28	155	155	10
	29	170	170	15
	30	185	185	15
	31	205	205	15
September	1	225	225	20
	2	250	250	25
	3	280	280	30
	4	320	320	40
	5	365	365	45
	6	395	407	42
	7	440	465	58
	8	520	555	90
	9	575	620	65
	10	635	690	70
	11	680	745	55
	12	720	800	55
	13	760	850	50
	14	800	900	50
	15	835	950	50
	16	880	1,010	60
	17	900	1,045	35
	18	920	1,075	30
	19	940	1,110	35
	20	955	1,140	30
	21	970	1,175	35
	22	980	1,205	30
	23	990	1,240	35
	24	995	1,275	35
	25	1,000	1,320	45
	26	1,005	1,370	50
	27	1,005	1,412	42
	28	1,005	1,470	58
	29	1,005	1,560	90
	30	1,005	1,625	65
Oct.	1	1,000	1,690	65
	2	980	1,725	35
	3	965	1,765	40
	4	945	1,795	30
	5	905	1,805	10
	6	870	1,820	15
	7	830	1,840	45
	8	790	1,835	0
	9	750	1,825	0
	10	710	1,820	0

Table 8. Estimated daily number of redds visible and redds constructed in the Skagit River (Cascade to Gorge powerhouse) in 1973 based on helicopter surveys.

Date		No. redds visible	Cumulative total redds	No. redds
August	15	0	0	0
	16	20	20	20
	17	50	50	30
	18	75	75	25
	19	95	95	20
	20	120	120	25
	21	150	150	30
	22	170	170	20
	23	195	195	25
	24	220	220	35
	25	245	245	25
	26	270	270	25
	27	295	295	25
	28	320	320	25
	29	340	340	20
	30	365	365	25
	31	390	390	25
September	1	415	415	25
	2	460	460	45
	3	500	500	40
	4	540	540	40
	5	580	580	40
	6	620	620	40
	7	670	690	70
	8	715	765	75
	9	800	875	110
	10	870	965	90
	11	950	1,070	105
	12	1,035	1,185	115
	13	1,135	1,305	120
	14	1,245	1,440	135
	15	1,350	1,570	130
	16	1,420	1,665	95
	17	1,490	1,760	95
	18	1,540	1,835	75
	19	1,580	1,900	65
	20	1,605	1,945	45
	21	1,605	1,970	25
	22	1,600	1,990	20
	23	1,590	2,005	15
	24	1,580	2,040	35
	25	1,540	2,040	0
	26	1,500	2,040	0
	27	1,440	2,020	0
	28	1,360	1,980	0
	29	1,280	1,970	0
	30	1,185	1,950	0
October	1	1,075	1,950	0
	2	1,015	1,980	30
	3	945	2,015	35
	4	885	2,070	55
	5	840	2,145	75
	6	795	2,235	90
	7	750	2,320	85
	8	705	2,370	50
	9	670	2,430	60
	10	640	2,475	45
	11	605	2,505	30
	12	590	2,535	30
	13	555	2,525	0

Table 10. Summary of 1973 Skagit River chinook egg retention observations.

Number of retained eggs	Number of females	Percentage
0-24	150	89.3
25-99	13	7.7
100-499	3	1.8
500-999	2	1.2
1,000 +	0	0.0
Total sampled	168	100.0

Table 11. Counts of chinook redds from five sections between the Sauk and Gorge powerhouse.

Section	Miles surveyed	October 1		October 18	
		No. of redds	Redds per mile	No. of redds	Redds per mile
Sauk to Cascade	10.8	997	92.3	343	31.8
Cascade to Diobsud	3.2	357	111.6	131	40.9
Diobsud to Bacon	1.7	220	129.4	102	60.0
Bacon to County Line	7.1	219	30.8	101	14.2
County Line to Newhalem	4.2	279	66.4	51	12.4
Total	27.0	2,072	76.7	728	27.0

Table 14. Peak fish-per-mile counts for Sauk River and Big, Buck, Tenas, and Sulphur Creeks, 1959-1972.

Stream	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Sauk River	22.7	102.6	101.3	50.4	38.3	20.9	61.9	41.9	10.3	4.5	30.0	32.7	18.7	50.6
Big Creek	20.0	21.7	63.3	26.7	28.3	6.7	33.3	43.3	88.3	25.0	23.3	35.0	23.3	28.3
Buck Creek	80.0	69.0	95.0	77.0	81.0	52.0	179.0	63.0	20.0	63.0	34.0	35.0	61.0	51.0
Tenas Creek	150.0	80.0	0.0	20.0	43.3	120.0	33.3	13.3	30.0	10.0	13.3	46.7	13.3	0.0
Sulphur Creek	236.6	120.0	276.6	483.3	173.3	46.6	250.0	326.6	246.6	260.0	320.0	363.3	593.0	770.0

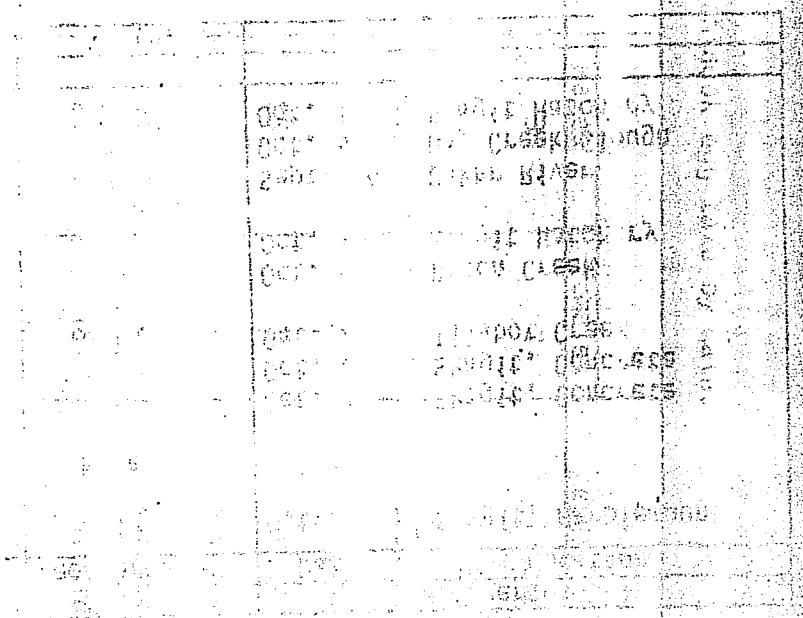


Table 15. Skagit[1/] and Sauk[2/] River peak chinook counts, 1952-1972.

Year	Skagit No. of fish/mile	Sauk total redds
1952	289	NS[3/]
1953	350	NS
1954	186	NS
1955	181	NS
1956	201	113
1957	167	35
1958	312	129
1959	313	NS
1960	628	322
1961	402	186
1962	244	NS
1963	173	202
1964	158	0
1965	272	119
1966	242	241
1967	124	NS
1968	260	113
1969	97	257
1970	251	491
1971	203	266
1972	270	439

1/ Sauk to Gorge powerhouse.

2/ Suiattle to Darrington.

3/ Not surveyed.

Table 16. 1973 Skagit juvenile chinook length frequency data.

Location	Date	Sample size	Average length (mm)	Range (mm)
Skagit River				
Marblemount	March 4	43	41.21	38-46
Marblemount	March 11	97	41.20	38-47
Marblemount	March 18	111	40.81	39-43
Rockport	March 4	35	40.63	38-44
Rockport	March 11	33	41.36	39-46
Rockport	March 18	24	41.71	40-46
Sutter Creek	March 11	64	40.98	39.44
Sutter Creek	March 18	54	40.30	37-46
County Line	March 27	64	40.61	36-44
✓ Hamilton	March 27	78	42.03	35-47
Sauk River				
Clear Creek	March 28	66	40.33	36-49
Below Suiattle	March 28	104	44.57	38-52
Suiattle River	March 28	63	39.58	36-49
Skagit River				
South Fork	April 5	64	42.35	39-48
Illabot Slough	April 8	10	42.30	40-45
✓ Sedro Woolley	April 8	32	44.28	36-50
Sauk River				
Near mouth	April 8	10	43.50	39-48
Below Suiattle	April 16	60	41.86	36-52
2 miles below Suiattle	April 16	14	41.35	37-45
1 mile below Suiattle	April 16	30	42.56	39-49
Skagit River				
✓ Hamilton	April 18	42 ? 115?	42.21	39-46
Sauk River				
Whitechuck	April 22	54	40.35	37-47
Clear Creek	April 22	149	41.55	36-49
Skagit River				
Bacon Creek	April 23	117	42.22	38-50
Suiattle River	April 23	158	42.19	36-55
Skagit River				
South Fork	April 26	29	42.27	39-48
Mt. Vernon	April 26	38	43.94	37-47
✓ Lyman	April 29	54 ?	42.40	39-49
Sedro Woolley	April 29	17	43.64	39-49
North Fork	May 3	117	47.59	39-65
North Fork	May 6	25	46.21	40-63
South Fork	May 6	19	44.10	40-49
Bacon Creek	May 9	55	44.30	39-52
Marblemount	May 9	83	43.09	36-52
Lyman	May 9	78	43.17	38-53
Swinomish Channel	May 10	42	49.09	38-94
Skagit River				
Sedro Woolley	May 13	70	45.68	40-55
Burlington	May 13	31	44.45	39-51
Mt. Vernon	May 13	25	47.32	38-54
North Fork	May 13	49	53.06	44-75
Sedro Woolley	May 20	212	43.27	36-53
Suiattle River	May 20	203	45.84	37-60
Sauk River				
Below Suiattle	May 21	225	49.17	40-58
Skagit River				
Bacon Creek	May 21	109	44.14	36-52
South Fork	May 22	6	53.66	44-70

Table 17. 1974 Skagit juvenile chinook mean lengths, spawning and non-spawning areas.

Sampling date	Location (weekly grouping)	Days between groups	Average length		
			Total river	Spawning area	Non-spawning area
March 4	Marblemount-Rockport		40.93	40.93	
		6			
March 11	Marblemount-Rockport		41.36	41.36	
		6			
March 18	Marblemount-Rockport		40.74	40.74	
		8.5			
March 27	County Line-Hamilton		41.78	41.78	
March 8	Sauk-Suiattle				
		9			
April 5	South Fork		42.97		42.35
April 8	Illabot-Lower Sauk-Sedro Woolley			43.74	
		8.5			
April 16	Sauk River		41.99	41.99	
		6.0			
April 22	Sauk River		41.96	41.78	
April 23	Bacon Creek-Suiattle				
April 26	South Fork-Mt. Vernon				43.21
		6.5			
April 29	Lyman		45.77	42.69	
May 3	North Fork				
		4.5			46.75
May 6	North and South Forks		44.20		
May 9	Bacon Creek-Lyman			43.42	
May 13	Lower Skagit		48.01	45.30	51.71
		6.5			
May 20	Sauk-Suiattle		47.56	45.85	
May 21	Bacon Creek-Sauk				
May 22	North and South Forks				51.89

Table 18. 1974 Skagit juvenile chinook mean lengths, spawning and non-spawning areas.

Sampling date	$\bar{x}$ Length	
	Spawning areas	Non-spawning areas
3/4	40.93	-
3/11	41.36	-
3/18	40.74	-
3/27, 28	41.78	-
4/5, 8	43.74	42.35
4/16	41.99	-
4/22,23,26	41.70	43.21
4/29, 5/3	42.69	46.75
5/6, 9	43.42	46.75

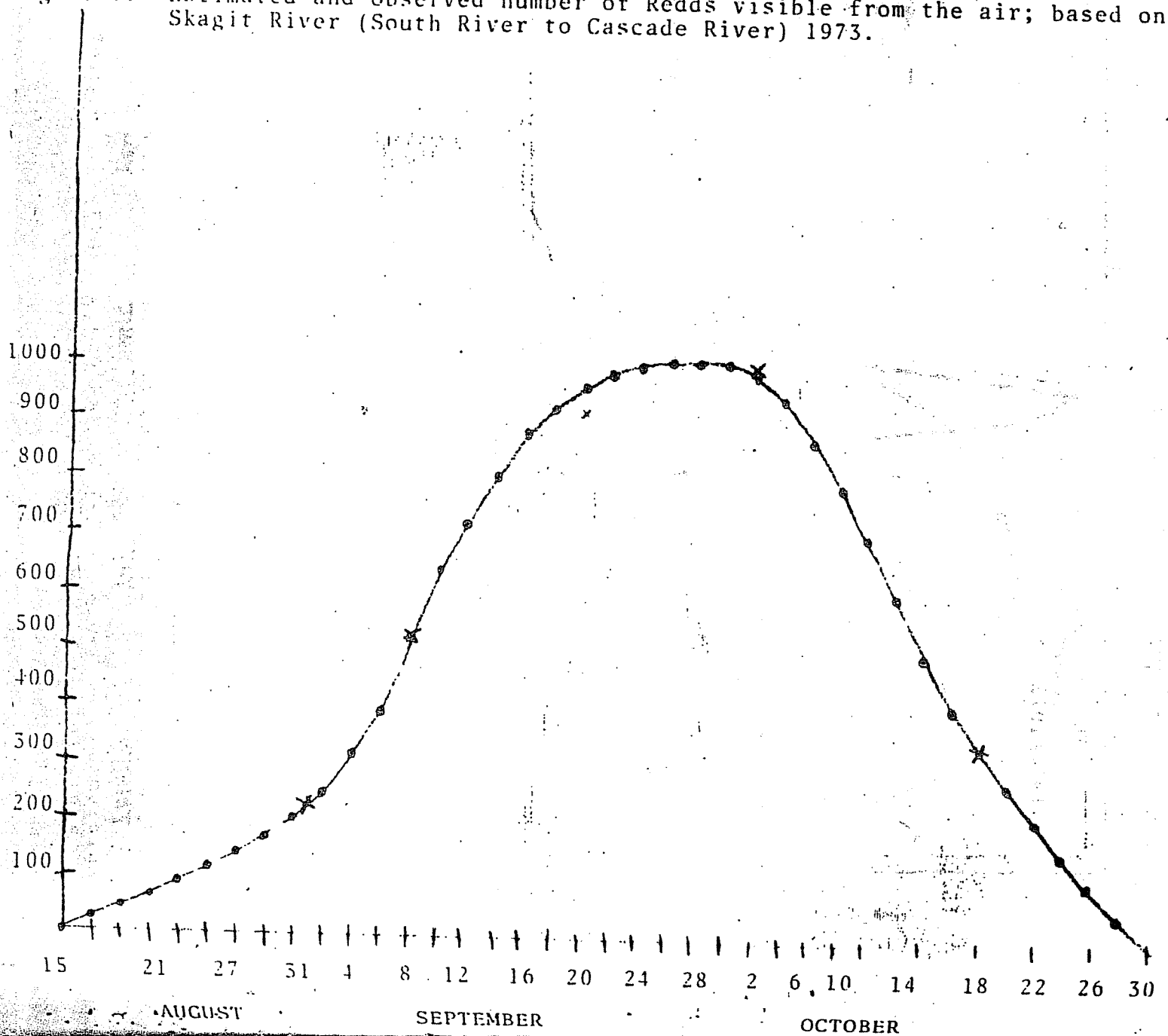
Table 19A. 1973 Skagit River juvenile salmon catch data.

Electro fishing data								
		Number of fish						
		Chinook		Coho				
Location	Date	0	1's	0's	1's	Chum	Pink
Skagit River							
Marblemount	3/4	43	0	0	0	0	0
Rockport	3/4	35	0	0	0	0	0
Sutter Creek	3/4	10	0	0	0	0	1
Marblemount	3/11	211	0	0	0	0	1
Sutter Creek	3/11	94	0	0	0	0	0
Rockport	3/11	39	0	0	0	0	0
Marblemount	3/18	23	0	1	0	0	1
Sutter Creek	3/18	112	0	2	0	0	0
Rockport	3/18	33	0	0	0	0	5
County Line	3/27	64	0	0	0	0	0
- Hamilton	3/27	78	0	0	0	0	0
Sauk River							
Clear Creek	3/28	66	0	0	0	0	0
Suiattle River	3/28	63	0	0	0	0	0
Sauk River							
Below Suiattle	3/28	104	0	0	0	0	0
Skagit River							
- Hamilton	4/18	115	0	0	0	13	2
Sauk River							
Whitechuck	4/22	54	0	0	0	0	0
Clear Creek	4/22	149	0	0	0	0	0
Suiattle River	4/23	163	0	5	2	0	0
Skagit River							
County Line	4/23	117	0	0	0	0	5
South Fork	4/26	29	0	0	0	5	5
Mt. Vernon	4/26	38	0	2	1	13	2
Bacon Creek	5/9	55	0	3	0	4	0
Marblemount	5/9	83	1	6	0	3	0
Rockport	5/9	78	0	3	0	13	0
Total		1,856	1	22	3	51	22

Table 19B. 1973 Skagit River juvenile salmon catch data.

Seine data								
Location	Date	No. of sets	Catch					
			Chinook		Chum	Coho	Chum	Pink
			0	1	0	1		
Skagit River								
South Fork	4/5	1	64	0	0	0	46	8
Mt. Vernon	4/5	1	23	0	0	0	3	0
- Sedro Woolley	4/8	2	32	0	0	1	4	0
Rockport	4/8	2	10	0	0	0	1	4
Marblemount	4/8	1	0	0	0	0	0	0
Sauk River	4/8	2	10	0	0	10	1	0
Skagit River								
- Concrete	4/8	3	3	0	0	0	1	0
- Lyman	4/8	2	3	0	0	6	1	0
North Fork	4/15	1	2	0	0	0	6	1
Sauk River	4/16	10	114	0	0	23	8	2
Skagit River								
- Lyman	4/29	2	71	0	0	0	3	2
North Fork	5/3	5	140	0	0	0	31	3
North Fork	5/6	4	111	3	0	2	1	1
South Fork	5/6	2	21	10	0	107	53	0
Rockport	5/7	6	33	0	7	4	4	0
- Sedro Woolley	5/13	2	70	1	0	1	21	0
Burlington	5/13	2	33	0	4	0	65	0
Mt. Vernon	5/13	2	27	0	0	0	65	0
North Fork	5/13	2	49	1	0	0	2	0
South Fork	5/22	1	266	6	0	24	33	0
North Fork	5/22	3	25	3	0	41	1	0
Total		53	1,103	24	11	219	363	20

Figure 6. Estimated and observed number of Redds visible from the air; based on helicopter surveys Skagit River (South River to Cascade River) 1973.



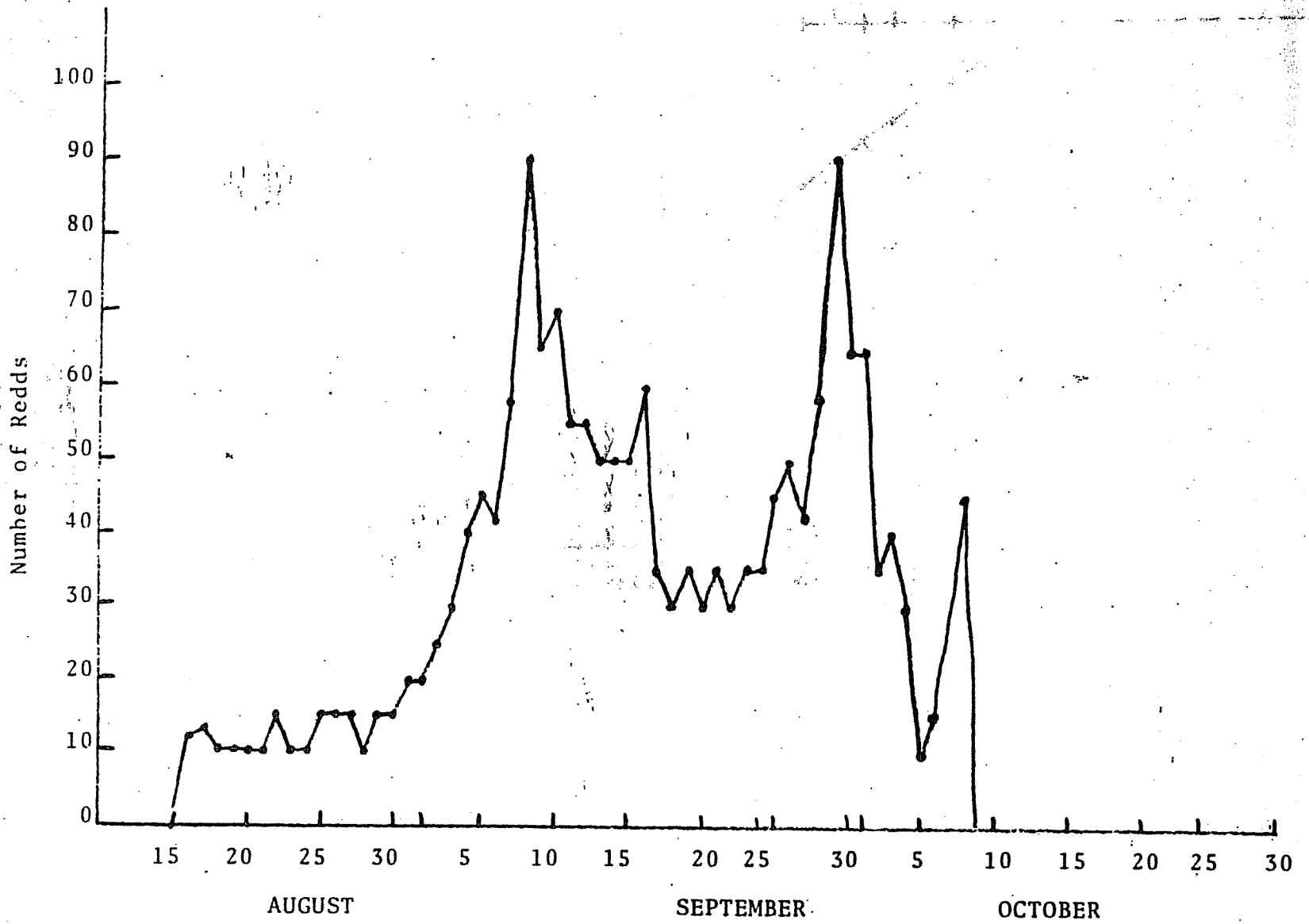


Figure 7. Estimated daily number of Redds constructed, Skagit River (Sauk to Cascade) 1973

Figure 8. Skagit River (Cascade River to Gorge powerhouse) on helicopter surveys, Estimated and observed number of Redds visible from the air based. 1973

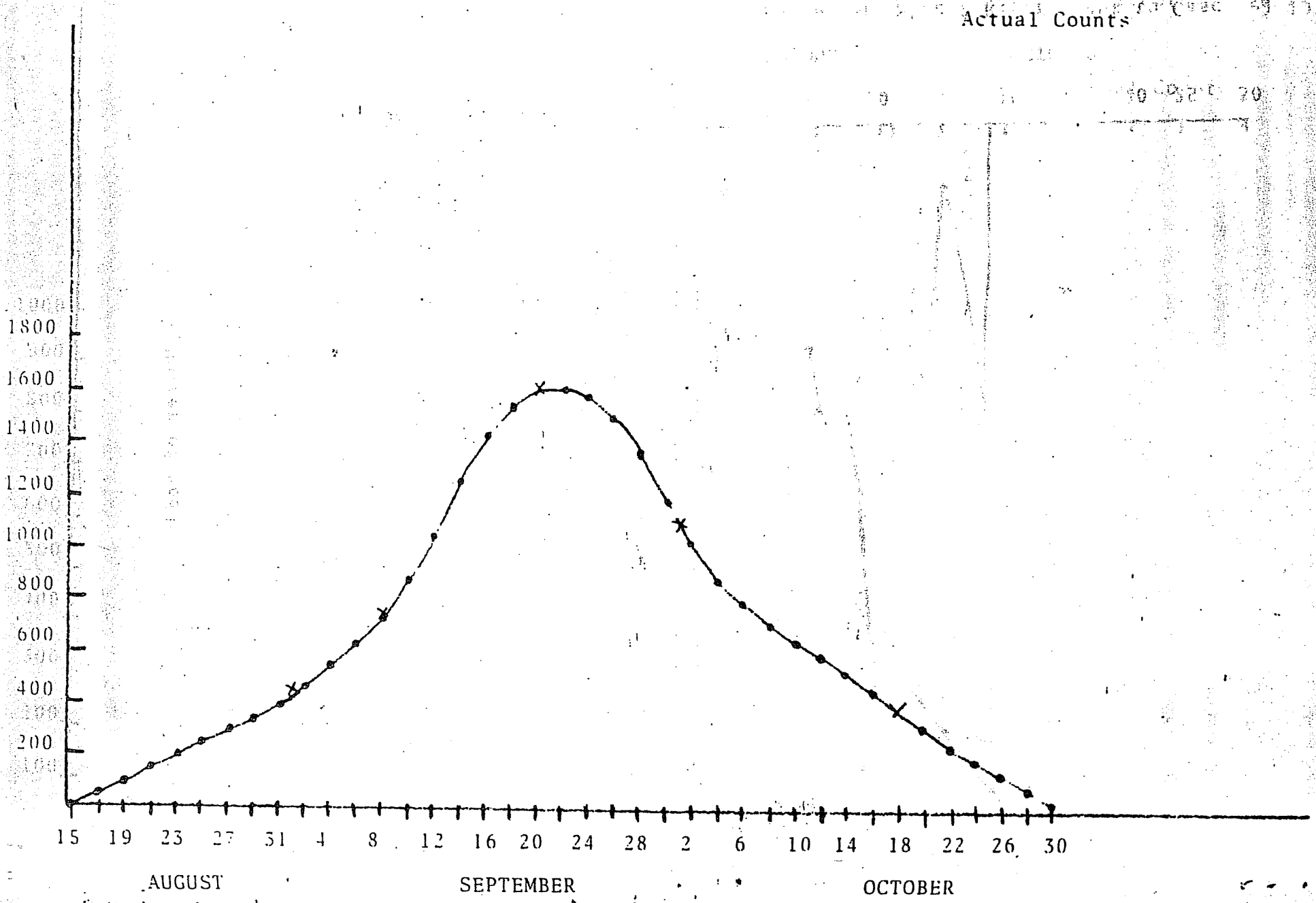
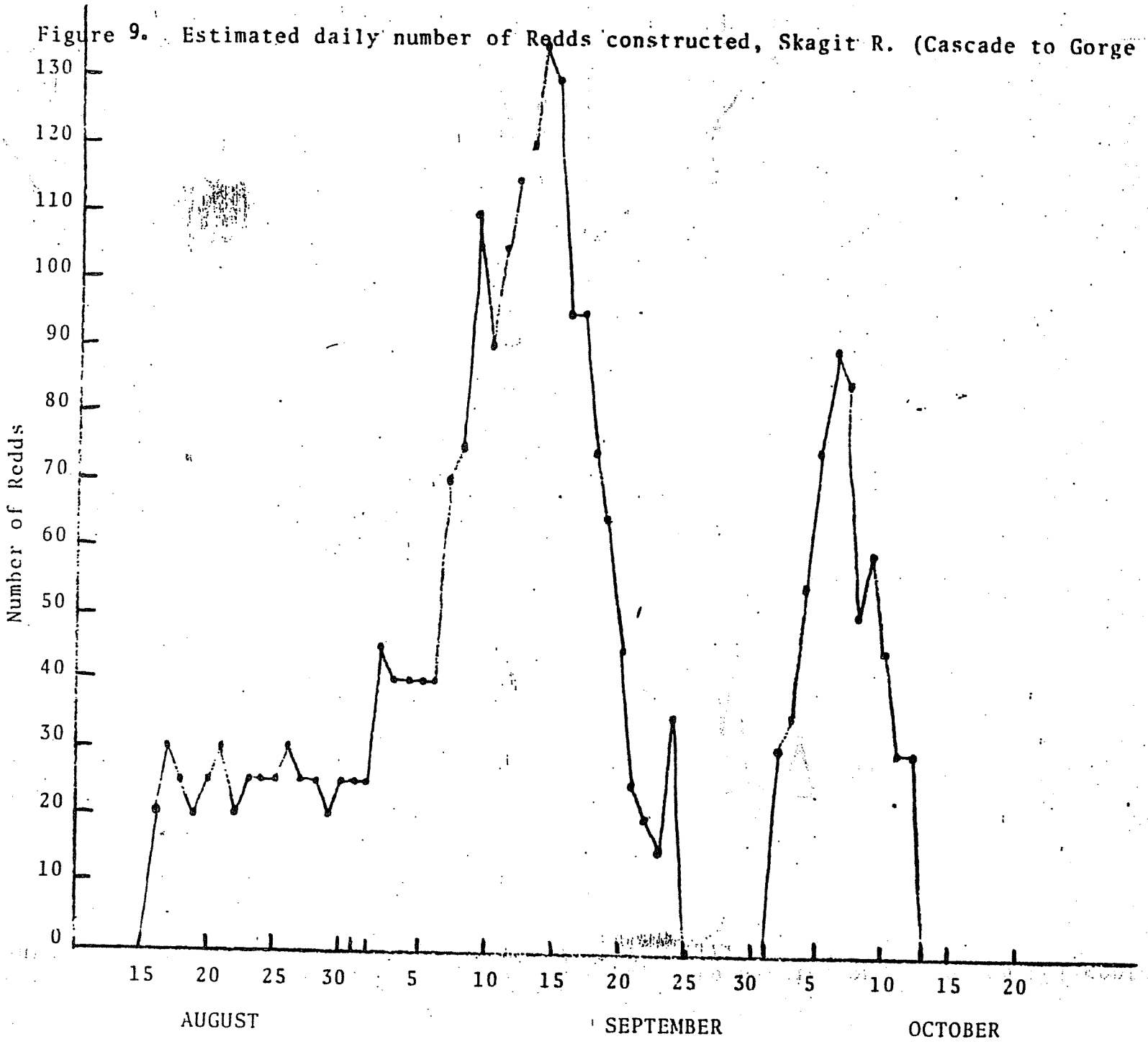


Figure 9. Estimated daily number of Redds constructed, Skagit R. (Cascade to Gorge powerhouse) 1973



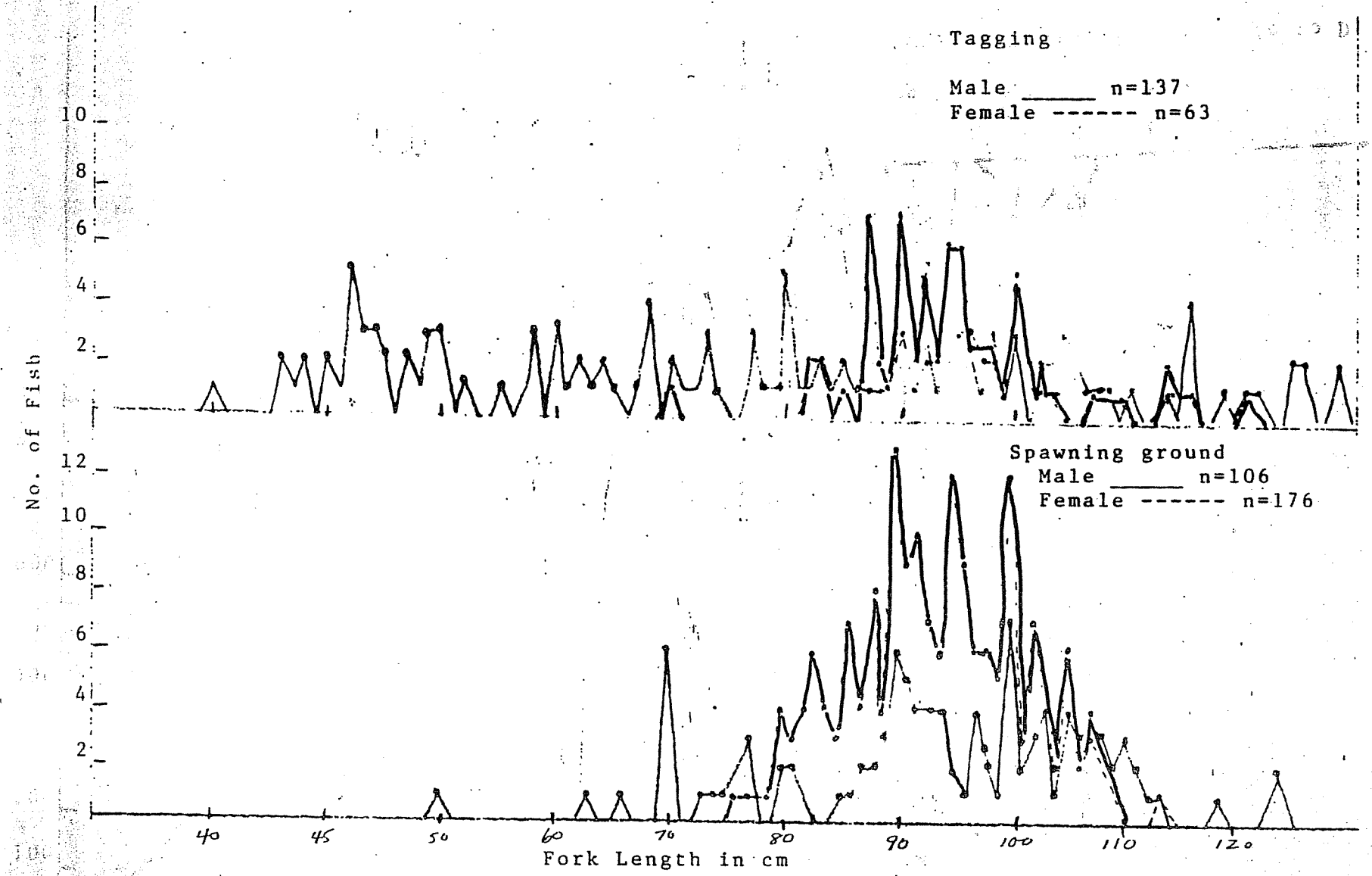
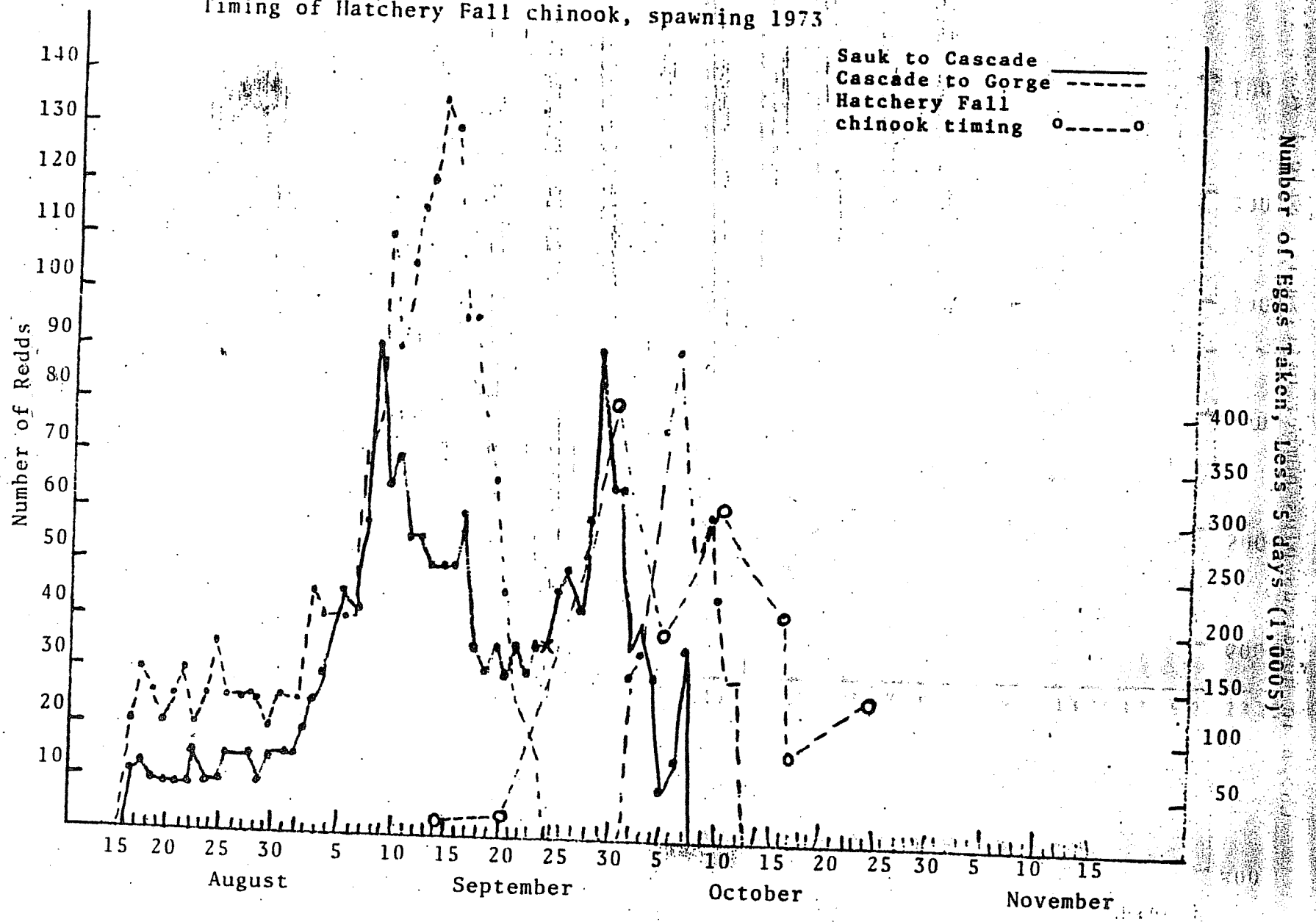


Figure 12. Skagit chinook length frequencies from tagging and spawning ground, sampling, 1973

Figure 13. Estimated daily number of Redds constructed, Skagit River (Saule to Cascade and Cascade to Gorge) and estimates

Timing of Hatchery Fall chinook, spawning 1973



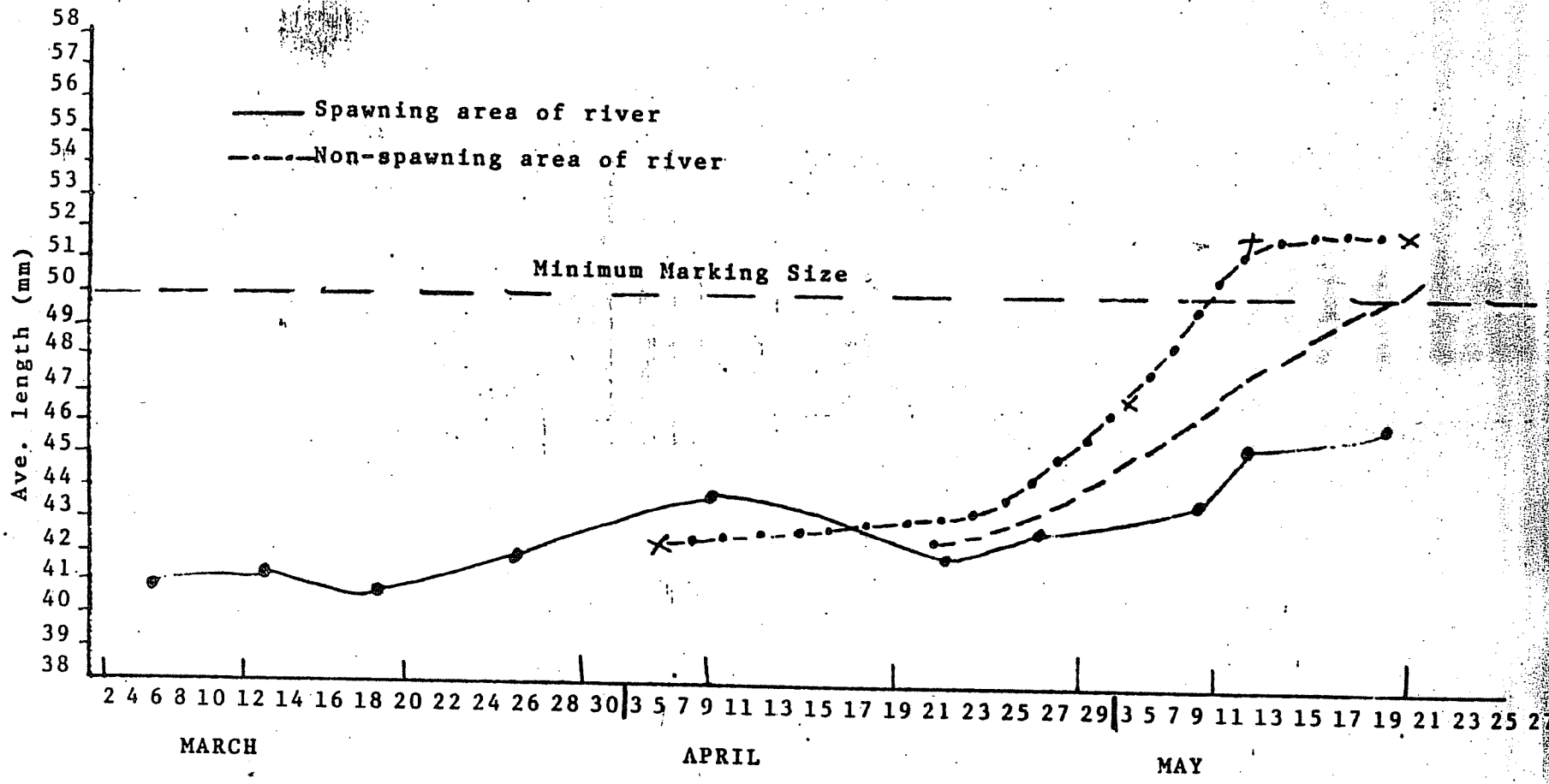


Figure 15. Mean chinook fry sample length, for spawning and non-spawning areas Skagit River, 1973.

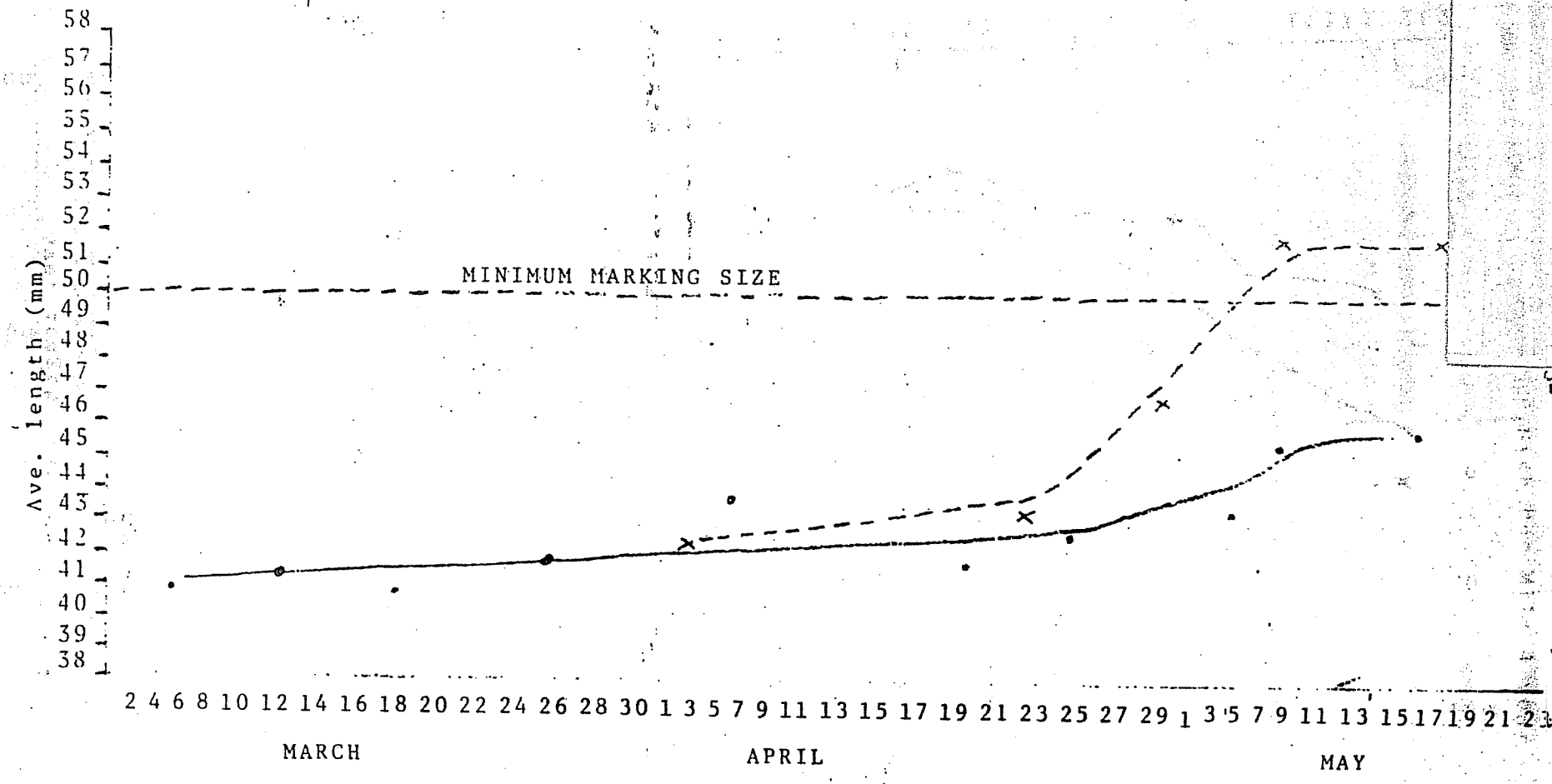


Figure 16. Estimated growth curve for chinook salmon fry by spawning and non-spawning areas, Skagit River 1973.