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ANADROMOUS SALMONID ESCAPEMENT STUDIES SOUTH FORK TRINITY RIVER 1984 THROUGH 1990

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ABSTRACT

Anadromous salmonids entering and spawning in the South Fork Trinity River were examined during the fall months of 1984 through 1989, and during the fall and late winter of 1990. Live fish were captured using a weir and fishtrap placed 2.3 km above the river mouth to document species composition, numbers, size of fish, run timing, sex ratios, spawning locations, spawning success, and straying of hatchery fish.

Fall-run chinook salmon (Oncoryhnchus tshawytscha), coho salmon (O. kisutch), and steelhead (O. mykiss) were observed in all years. Spring-run chinook salmon sampling was done in 1986. Chum salmon (O. keta) were observed in

four years. A brown trout (Salmo trutta) was captured in 1990.

Fall-run chinook salmon escapement estimates ranged from a high of 2,640 fish in 1985 to a low of 345 fish in 1990. Coho salmon escapement in 1985 and 1990 was estimated at 127 fish and 99 fish, respectively.

Coded-wire tags (CWTs) recovered from fall-run chinook salmon from 1985 through 1988 indicated that the majority of straying hatchery fish originated from within the Trinity River basin. CWTs recovered from coho salmon in 1985 indicate that these fish originated from Trinity River Hatchery (TRH). Chinook salmon released from TRH as yearlings or yearling+ strayed at a higher rate than fingerling releases.

INTRODUCTION

The South Fork Trinity River (SFTR) is the largest tributary to the Trinity River and is an important spawning and rearing area for anadromous salmonids, particularly chinook salmon (Oncorhynchustshawytscha), coho salmon (O. kisutch) and steelhead trout (O. mykiss).

Information on the status and biology of these resources is important for their protection and for the management of the ocean and in-river fisheries that depend upon them for commerce and recreation. Here we present the results of a six-year field study of the anadromous salmonid runs of the SFTR.

Study objectives were:

1. Determine the species composition of the anadromous fish runs,
2. estimate the anadromous salmon and trout escapements,
3. determine run-timing for each salmonid species,
4. determine the sizes of salmonids in the runs,
5. document hatchery salmonid straying,
6. describe sex ratios, and
7. document locations and success of spawning activities.

STUDY AREA

The SFTR is located in northern California, about 70 km west of Redding and 90 km east of Eureka (Figure 1). The watershed encompasses 2,640 km^2 and is sparsely populated. The river originates in the Yolla Bolla Mountains at an elevation of 2,397 m and flows about 145 km to its confluence with the main stem Trinity River. The major tributary to the SFTR is Hayfork Creek which drains an area of 982 km^2 and enters near the town of Hyampom at river km (RK) 48.4 (Figure 2).

The average annual discharge of the SFTR basin is 1.36 km^3 (Rantz 1964). Maximum mean monthly discharge generally occur between January and March, while minimum discharge occurs in August and September. The maximum daily discharge on record was estimated at 2,492 m^3/s in December 1964 at the United States Geological Survey (USGS) gaging station located 5.8 river km below the mouth of Hayfork Creek. The minimum daily discharge was 0.4 m^3/s at the Hyampom gaging station; it occurred August 25, 1977 during drought conditions.

FIGURE 1. Map of the Klamath-Trinity River basin depicting the location of major landmarks.

FIGURE 2. Map of the South Fork Trinity River basin depicting the location of major landmarks.

Salmonid Resources

Fall-run chinook salmon escapement into the SFTR was estimated in 1964 at 3,337 fish (LaFaunce 1967). More recently, fall-run chinook salmon escapements have been estimated at 249 in 1980 and 230 in 1982 (T. Mills, Calif. Dept. Fish Game, pers. comm.). Efforts by the California Department of Fish and Game (DFG) to estimate fall-run chinook salmon escapements into the basin during the 1981 and 1983 seasons using salmon carcass mark-and-recovery techniques proved futile because of apparently small escapements, and highly variable flow patterns that prevented adequate carcass recovery (T. Mills, Calif. Dept. Fish Game, pers. comm.).

Spring-run chinook salmon escapement into SFTR was estimated in 1964 at 11,604 fish (LaFaunce 1967). Recent snorkel surveys, conducted by U. S. Forest Service (USFS) and DFG personnel, have indicated a decline in the population size. For example, between 1970 and 1991, the number of spring-run chinook observed ranged between 7 and 342 fish (D. Irizarry, U.S. For. Serv., pers. comm.). DFG personnel, using mark-and-recovery techniques, estimated that the spring-run chinook salmon escapement in 1991 was 268 fish (M. Dean, Calif. Dept. Fish Game, pers. comm.). This estimate is preliminary and subject to revision.

One reason for the decline in the chinook salmon escapements has been attributed to loss and degradation of instream habitat conditions (Buer and Senter 1982). Pool habitat and spawning riffles have filled with debris, and fine sized sediment has reduced the average bed load particle size. Smaller sized particles are more easily moved, resulting in higher stream bed movement which can destroy redds (Morisawa 1968).

LaFaunce (1967) found that spring-run and fall-run chinook salmon spawning in the SFTR was separated by area and time. Fall-run chinook salmon used the lower 48 river km below Hyampom Valley, while spring-run chinook salmon used the upper drainage. Spring-run chinook salmon also spawned earlier (mid-October peak) than fall-run chinook salmon (mid-November peak).

No steelhead escapement estimates are on record prior to this study.

The relative abundance of summer-run steelhead present in the SFTR basin has been monitored for ten of 13 years (between 1979 and 1991) by snorkel surveys conducted primarily by the USFS. The number of fish observed ranged from 3 to 91 fish (D. Irizary, U. S. For. Serv., pers. comm.). In 1989, the South Fork Trinity River Steelhead Study (DFG) initiated trapping and tagging efforts to determine the annual winter-run steelhead escapement.

Except for the coho salmon escapement estimates contained in this report, we are aware of no other escapement estimates that are on record.

Historically, the California Division of Fish and Game planted the SFTR, near Forest Glen (Figure 2), with other species of salmonids. Brook trout (Salvelinus fontinalis) were planted in 1930, 1933 and 1938, and brown trout (Salmo trutta) were planted in 1932 (Calif. Div. Fish Game stocking records, unpublished data).

METHODS AND MATERIALS

Trapping Operations

A weir and fishtrap were placed in the SFTR near Sandy Bar (RK 2.3) to catch upstream migrating salmon and steelhead (Figure 2). It was operated between September and November from 1984 through 1988, except in 1986 when the weir was installed in mid-August and in 1990 when the weir was operated into March 1991. The weir sampled essentially all upstream migrating salmonids entering the basin as no tributary spawning streams were located between the river mouth and the trapping location, and limited amounts of spawning gravel was present downstream of the weir.

Chinook salmon trapped on or after September 1 of each year were assumed to be fall-run while those trapped prior to September 1 were assumed to be spring-run.

The weir spanned the entire width of the river (about 70 m), with the trap located in the thalweg. The trap was 2.4 m W x 2.4 m L x 1.2 m H and constructed of marine plywood flooring with sides and top formed by a combination of vinyl-coated chain link fence and 1.9-cm EMT conduit panels. Weir panels used from 1984 through 1988 were 1.2 m H x 1.5 m W, and constructed of 1.9-cm EMT conduit welded to angle iron frames with 3.2-cm horizontal bar spacing. Panels were placed end-to-end in a "V" configuration leading upstream, directing fish toward the trap. Panels were propped upright, and supported and held in place with metal fence stakes; the entire weir was tied together using bailing wire. In 1989 and 1990, an "Alaska"-style weir panel and support system were used. This consisted of wooden tripods supporting 1.9-cm EMT conduit held vertically, with 2.5-cm bar spacing.

The trap was fished seven days per week except when high flows prevented safe operation. The trap was checked for fish at least once in the morning and once in the evening. Each salmonid captured was identified to species, measured to the nearest cm fork length (FL), examined for fin marks and external tags, and sexed. We attempted to remove a scale sample from all salmonids captured: often scales were embedded, preventing their removal. Scales were obtained from the left side at a location slightly above the lateral line and posterior to the insertion of the dorsal fin.

During trapping operations, tags were applied to those fish which appeared healthy. Fish deemed to be in poor condition were examined and released above the weir. Between 1984 and 1988, salmon were tagged with serially numbered nonreward spaghetti tags. Starting in 1986, all project-tagged chinook also received an opercular punch, using a standard paper punch, as a secondary identifying mark. This was done to determine the tag shedding rate based on subsequent carcass sampling.

Fish captured bearing external tags from other tagging operations in the Klamath-Trinity River basin were examined for tag number and condition and released above the weir.

Steelhead were tagged in 1984 with serially numbered nonreward spaghetti tags, but were not tagged in 1985. Steelhead tagging resumed in 1986 and continued through the 1988 trapping season. Ten dollar reward anchor tags were used during this period. This was done to estimate steelhead angler harvest (as part of the Model Steelhead Stream Demonstration Project, Irizarry et al. 1985).

Salmon and steelhead tagged at the SFTR Weir that died without spawning and were recovered within four days of tagging above the weir, were classified as tagging mortality, as were all tagged fish recovered downstream of the weir.

Flows at the weir site were measured at the nearby USGS gaging station (Figure 2).

Carcass Surveys

Salmon carcass surveys were conducted on two sections of the SFTR in order to recover tagged (and untagged) fish (Figure 3). The upper survey section extended from about RK 37 to RK 56 and was characterized by a wide floodplain, low gradient, and substrate ranging from sand to small cobble. This section was surveyed on foot and included the Hyampom Valley and the lower 5.5 river km of Hayfork Creek. The lower section extended from the weir site to about RK 22 and was characterized by narrow floodplain and steep gradient. This section was surveyed by kayak or whitewater raft. Survey crews surveyed both sections on a weekly basis until high flows or high turbidities prevented carcass recovery efforts. The species, FL, sex and the presence of any fin marks or tags were recorded for all carcasses recovered. For this report, we assume all chinook salmon recoveries were fall-run.

Sex ratio (male:female) was determined from data collected during the carcass surveys. Prespawning mortality rate for salmon was calculated by dividing the number of unspawned females by the total number of females found. Carcasses judged to contain 50% or more of their eggs were classified as unspawned.

FIGURE 3. Map of the South Fork Trinity River depicting the location of carcass recovery survey sections (shaded areas) and major landmarks.

The location of redds was used to identify salmon spawning areas. Since we could not tell which species or race excavated the redds observed, we described spawning areas in general terms rather than attempting to discriminate between species. In 1984, because of high flows and turbidity hindering conditions, carcass recovery surveys were terminated early and thus DFG personnel did not have many opportunities to count and map redds. Where possible, redd locations listed on carcass recovery survey data sheets were tabulated; however, in some years (1985, 1986, and 1987) redd locations were not consistently recorded because mapping of spawning areas was not an objective of the carcass recovery surveys. Therefore, only incidental observations are available. In an effort to identify spawning areas in those years, we have tabulated the location of redds measured as part of a study that described physical attributes of chinook spawning habitat in the SFTR (Mills 1991). In 1988, 1989 and 1990, the number of redds and their locations was consistently recorded, and were used to delineate spawning areas. Spawning periods were determined by tabulating the number of newly excavated redds observed through time.

Data Analysis

The size to separate grilse (age 2) from adult (age > 2) salmon was determined either by scale analysis (fall-run chinook) or through length frequency analysis (coho salmon and steelhead). Fall-run chinook salmon scale samples collected in all years were mounted on glass microscope slides and read using a microfiche projector to determine age. Because the size separating grilse from adults is generally located between 50 and 65 cm FL (B. Heubach, Calif. Dept. Fish Game, pers. comm.), we read all scales collected from fish measuring 65 cm FL and smaller. We then selected a fork length to separate grilse from adults that resulted in the fewest number of misclassified fish.

For all years, we used the size separating coho salmon grilse from adults based on fork length data collected by DFG personnel at the nearby Willow Creek Weir, located on the mainstem Trinity River, approximately 2.3 river km downstream of the confluence with SFTR (Figure 1). The nadir in the length frequency distribution range of 50-60 cm FL was assumed to separate grilse from adults.

The size separating steelhead adults from half-pounders for each year was based on length frequency data collected by DFG personnel (Klamath River Project) at a seining site in the Klamath River estuary near Waukell Creek, approximately 118 river km downstream (Figure 1). The nadir in the length frequency distribution range of 35-45 cm FL was assumed to separate half-pounders from adults.

Escapement estimates were based on the adjusted Petersen formula (see Ricker 1975):

$$N = (M + 1) \times (C + 1) / (R + 1)$$

where : N = size of population

M = number of fish marked

C = catch or sample taken for census

R = number of recaptured marks in the sample

Confidence limits were determined using either the Poisson or binomial approximations following criteria described by Chapman (1948).

To determine if tagged fish randomly mixed with untagged fish, we compared grilse:adult ratios of effectively tagged fish with the grilse:adult ratios of fish recovered in the carcass recovery surveys (chi-square). If the observed grilse:adult ratios were independent of the weir and carcass sampling locations ($P > 0.05$), then random mixing was assumed and grilse and adult data was combined to estimate escapement. However, a significant difference in the grilse:adult ratios suggests that these components of the population are not randomly mixed; therefore, the escapement estimate was stratified by grilse and adults.

In 1989, we departed from the method outlined above to calculate the escapement estimate, because only a few tags were recovered in the lower carcass survey section and no tags were recovered in the upper carcass survey section. In an effort to increase the number of tag recoveries used to calculate the Petersen estimate, we chose to use only a part of the data collected from the upper carcass survey section and use data collected from a different source. We used trapping data collected at the Hyampom Valley Weir (RK 41) operated by the SFTR Steelhead Study (Figure 3).

The Hyampom Valley Weir was being operated to trap steelhead in an effort to estimate their escapement into the SFTR basin. This weir also captured fall-run chinook salmon; some of which were recaptures (tagged at the SFTR Weir). We summed the number of tagged and untagged fish recaptured at the Hyampom Valley Weir with the number of tagged and untagged carcasses recovered between the two weirs to obtain Petersen estimate factors C and R. This method was only available for 1989 since the Hyampom Valley Weir was operated for just that one year.

The hatchery component of the escapement in 1985 through 1990 was estimated based on the number of fin-marked fish captured at the weir. No attempt was made to estimate the number of hatchery fish in the 1984 escapement. Subsampling of Ad-marked salmon for coded-wire tags (CWTs) was done by two methods: 1) in 1985 and 1986, heads from Ad-marked fish recovered during the carcass surveys were taken to obtain CWTs; 2) in 1987 and 1988, subsamples of the Ad-marked fish captured at the weir were sacrificed to obtain CWTs.

Generally, only a percentage of a hatchery's release are marked or coded-wire tagged. Assuming that the survival and return of marked and unmarked fish is the same and the mark identifies a given release group, the total number of fish present in the weir catch from a given hatchery release can be estimated. We used the following steps to extrapolate the total number of hatchery-origin fish trapped at the weir: 1) The percentage of each coded-wire tag group (bicode) in the sample of heads containing CWTs was calculated (relative frequency), 2) because some heads taken contain no CWTs (Ad+No CWT) and we released some Ad-marked fish (head not taken), we apportioned these fish (unknowns) among the bicodes recovered according to the relative frequency of the known bicodes, 3) for each bicode, these apportions were then added to the number of fish recovered to estimate the number of fish recovered belonging to each bicode, 4) to account for unmarked fish that were also a part of a hatchery release group, we calculated the Ad-marked rate (total number Ad-marked released/number of all fish released), 5) the total number of hatchery fish in the weir catch, including unmarked hatchery fish, for each release group, was extrapolated by dividing the estimated number of Ad-marked fish from each tag group recovered by it's Ad-marked rate, and 6) finally, release group percent contribution of the weir catch was calculated by dividing the extrapolated number of hatchery fish by the total weir catch. The percent hatchery fish in the escapement was assumed to be the same as that observed at the weir, and the remainder was assumed to be the wild stock component. Hatchery release information was obtained from Johnson and Longwell (1991).

To illustrate the above procedure assume that 1,000 fall-run chinook salmon were trapped, of which 100 were Ad-marked. A total of 50 samples (heads) were taken from Ad-marked fish; CWTs were recovered from 40 heads as follows: 30 from bicode Ad_a, 10 from bicode Ad_b, and 10 Ad+No CWT. We can now identify where 40 (known) of the 100 Ad-marked fish originated (60 unknown): (1) We apportioned the 60 unknown origin fish among the 2 bicodes (known origin fish) according to their relative frequency. The relative frequency of bicode Ad_a and Ad_b were 75% (30 Ad_a/40 known) and 25% (10 Ad_b/40 known), respectively. (2) Thus, 75% of the unknown fish were assigned to Ad_a (60 unknown x 75% = 45 fish), while 25% were assigned to Ad_b (60 unknown x 25% = 15 fish). (3) We summed the actual number of CWTs recovered with the apportioned unknowns for each bicode; this yields the total number of fish from that bicode that was caught in the weir: Bicode Ad_a = 30 recoveries + 45 apportioned = 75 Ad-marked fish, and Bicode Ad_b = 10 recoveries + 15 apportioned = 25 Ad-marked fish. (4) For each hatchery release group, the number of fish caught at the weir was divided by it's percent Ad-marked rate to estimate the total number of fish (Ad-marked and unmarked) caught. Let us assume that for release group Ad_a, 50% of the hatchery fish were tagged (CWTs), while for Ad_b only 10% of the release group contained tags, then: (5) Bicode Ad_a = 75 fish / 0.5 Ad-marked rate = 150 total weir catch, and Bicode Ad_b = 25 fish / 0.1 Ad-marked rate = 250 total weir catch. (6) The contribution to the weir catch for release groups Ad_a and Ad_b is 15% (150 bicode Ad_a/1,000 weir catch) and 25% (250 bicode Ad_b/1,000 weir catch), respectively.

RESULTS AND DISCUSSION

Species Composition

Relative species composition observed during the trapping season was based on the numbers of fish captured at the weir.

Five species of salmonids-chinook salmon (spring- and fall-run), coho salmon, chum salmon (O. keta), steelhead, and brown trout (Salmo trutta)-were captured during trapping operations (Table 1). Fall-run chinook salmon, coho salmon, and steelhead were observed in all years. Fall-run chinook salmon was the most abundant species in five of the seven years sampled, comprising between 48.3% and 63.6% of the catch. Steelhead was the most abundant species in 1985 and 1986, and comprised 41.8% and 57.2%, respectively, of the catch. Coho salmon were relatively scarce in all years (<3%), except in 1985 and 1990 when they comprised 22% and 13.2% of the catch, respectively. Spring-run chinook salmon were captured in 1986 when trapping began in mid-August. Chum salmon were observed in 4 seasons, with a high catch of 3 fish in 1985. One brown trout was observed in 1990.

The capture of adult chum salmon during this study is the first confirmed record of their presence in the SFTR. The possibility exists that, these fish are strays from other populations. However, they might be the remnants of a once relatively abundant population that existed in the SFTR basin; long-time resident Mr. Gary Carpenter (pers. comm.) stated that chum salmon were once quite common in the SFTR.

The presence of brown trout have been recorded elsewhere in the Klamath-Trinity River basin. Brown trout adults have been trapped at the Junction City (JC) Weir, located on the mainstem Trinity River (Figure 1). Generally, the JC Weir is operated from May through November. Peak brown trout catches generally occur in June and July (B. Heubach, Dept. Fish Game, pers. comm.). Two juvenile brown trout were collected in the Klamath River estuary in 1991 (M. Wallace, Calif. Dept. Fish Game, pers. comm.), and juvenile brown trout were reportedly collected in 1986 (M. Pisano, Calif. Dept. Fish Game, pers. comm.). The single brown trout captured in the SFTR may be a stray from the population seen at the JC Weir, or may be part of a separate population using the SFTR.

Spawner Escapement Estimates

Fall-run Chinook Salmon

Chi-square analysis indicated that effectively tagged grilse and adults randomly mixed with untagged fish in 1985 through 1990 (Table 2). Therefore, all escapement estimates were non-stratified.

Annual fall-run chinook salmon spawner escapements were calculated for 1985 through 1990 (Tables 3 and 4). We were unable to calculate an escapement estimate in 1984 because high flows prevented carcass recovery efforts. The highest escapement was observed in 1985 at 2,640 fish. Escapement decreased markedly until the lowest escapement, 345 fish, occurred in 1990 (Figure 4). In 1985, grilse greatly outnumbered adults (grilse:adult ratio = 2.26), while in 1986, 1987, and 1989 adults were more numerous (grilse:adult ratios; 1986 = 0.43, 1987 = 0.22, and 1989 = 0.16). In 1988 and 1990, grilse and adults escapements were similar (grilse: adult ratios; 1988 = 1.14 and 1990 = 0.99).

Spaghetti tag shedding rates for fall-run chinook salmon in 1985-90 ranged from 4.5 to 28.6%, and averaged 15.4% (Table 5). No data on tag shedding is available for 1984 because high flows prevented carcass recovery efforts.

Based on this work, adult fall-run chinook salmon spawner escapements into the SFTR basin have declined from the 1985-86 level. Overall, escapement appears to have declined 90%, from 3,337 fish observed in 1964 (LaFaunce 1967), to 345 fish observed in 1990. A similar trend has been observed with the fall-run chinook salmon spawner escapement within the entire Klamath-Trinity River basin and within the Trinity River basin. The total Klamath-Trinity River basin spawner escapements declined from a peak observed in 1986 of 180,263 fish to 14,073 fish in 1990 (Figure 5) (Calif. Dept. Fish Game 1991).

Several factors have been identified as contributors to the observed decline in the salmon population. These include poor water quality, recent poor ocean conditions (El Nino), drought, poor land management practices, loss of habitat due to dam construction, overfishing, hatchery practices, and others. If we desire to stabilize and restore the salmon populations in the Klamath-Trinity River basin, then all resource agencies, user groups, land management agencies, and land managers must make a whole-hearted commitment to this goal.

Coho Salmon

Sufficient numbers of coho salmon were tagged and recovered in 1985 and 1990 to make escapement estimates for those years. A test of independence (chi square) indicates that in 1985 tagged fish did not randomly mix with untagged fish (Table 2), and we calculated a stratified escapement estimate. In 1990, we did not capture (or tag) any grilse at the weir, but did recover 2 untagged grilse in the carcass recovery surveys (Table 4). For 1990, we calculated an adult escapement estimate and added two grilse (carcass recoveries) to obtain a total escapement figure. The escapements in 1985 and 1990 were estimated at 127 and 99 coho salmon, respectively (Table 3, and Figure 6). Adults outnumbered grilse in 1985 (grilse:adult ratio = 0.40), while the 1990 escapement was comprised essentially of adults (Table 4).

Spaghetti tag shedding rates for coho salmon ranged from 0% to 4.5%, and was 4.5% in 1985 and 0% in 1986-1990 (Table 5). No data on tag shedding rate are available for 1984 because high flows prevented carcass recovery surveys.

Run Timing

Fall-run Chinook Salmon

In general, fall-run chinook salmon began to enter the SFTR in mid-September, with the frequency of fish moving upstream increasing through the end of October (Figure 7, and Tables 6-12). In four of seven trapping seasons, the overall weekly catch rate peaked during the week ending (WE) October 28. The peak in all years occurred between WE September 16 and November 18. The number of fish trapped in the SFTR then decreased through November and December. During the 1990-91 trapping season (our longest sampling effort), grilse were caught until late January, and adults were caught through mid-December.

A two-way test of independence (G-test) indicated that in 4 of 7 years the timing of the grilse and adult runs in the SFTR did not coincide ($P < 0.05$); in 1984, 1987 and 1989, the grilse and adult runs did coincide. It appears that larger numbers of grilse tended to move into the SFTR basin before adults in 2 of 4 years (1985 and 1986). In 1988, adults entered the basin first and their numbers steadily increased to a peak during the WE October 28; the grilse catch curve remained steady at a relatively high level for three weeks before peaking during the WE October 28. In 1990, adults moved into the basin before the grilse.

Catch efficiency (defined as the number of fish that are caught/the number of fish moving past the weir) at the weir may bias these observations because efficiency likely decreases with increased flow, which generally begins during October or November due to seasonal storms. Peak catches generally correspond with an increase in flow. For example, the peak catch in 1985 (7.0 fish/night) occurred WE October 21 (from 1.6 fish/night during WE October 14) and was associated with a flow increase from 1.7 m^3/s to 2.5 m^3/s (Table 7, and Appendix 1(KRIS NOTE: Appendices not included. Please contact author if appendices are needed). It is interesting to note that although flow increased again the following week (to 7.1 m^3/s), weekly catch rate decreased to 1.6 fish/night during WE October 28, the same level it had been the WE October 14. This might reflect a response of salmon (holding downstream) to a sudden flow increase from relatively low levels. Rising and falling water levels result in "pulses" of fish past a given point as the fish move between holding areas.

Peak weekly grilse and adult catch rates at SFTR Weir generally occurred between 5 to 7 wks after peak catches were observed at the DFG beach seining site in the Klamath River estuary (Table 13). One exception occurred in 1986, when peak catches occurred simultaneously during WE September 16, which is about 4 wks earlier than normal. During 1986, early rains and increased flow may have stimulated movement of salmon into the SFTR basin from downstream holding areas. It is not likely that the same school of fish traveled the 118 river km between both sampling sites in the same week; most likely, both sites sampled separate schools of fish. The other exception was observed in 1990, when peak catches of grilse and adults occurred 10 wks and 9 wks, respectively, after the peaks occurred in the estuary.

Peak weekly grilse and adult catch rates generally occurred between 3 and 6 wks after peak catch rates were observed at the Willow Creek Weir (Table 13). The exception occurred in 1986, when peak catches at the SFTR Weir occurred 1-wk before the peak catch occurred at the Willow Creek Weir. It is possible that two schools of fish moved through the weirs independently of each other; one school located between the two weir sites homing-in to the SFTR basin, and the other school located a longer distance downstream of the Willow Creek Weir. If both schools moved in response to the flow increase that occurred in late September 1986 (Figure 7), and at the same rate, then it is possible for peak catches at the Willow Creek Weir to occur after the peak at the SFTR Weir because of the longer distance covered. The largest difference between peaks in the run (9 wks) occurred for grilse in 1990; low flows in the SFTR may have delayed movement into the basin.

Coho Salmon

Coho salmon run timing can only be described for 1985 and 1990 because few fish were caught during the other years (maximum of 17 fish in 1987). In 1985, both the grilse and adult runs peaked during WE November 11, and were in progress when the weir was removed in late November (Figure 8, Tables 6-12, and Appendix 1). During the 1990-91 trapping season, only adults entered the SFTR basin, and the run peaked during WE January 14.

Coho salmon grilse and adult runs peaked at the SFTR Weir in 1985 3 wks after a peak was observed at the Willow Creek Weir, while in 1990-91 the SFTR catch rate for adult coho peaked 12 wks after the Willow Creek Weir catch rate (Table 13). We could not determine the elapsed time between the peak run at the SFTR Weir and the Klamath River estuary (near Waukell Creek) because seining was terminated before the run peaked in the estuary.

A two-way test of independence indicated that in 1985, the grilse and adult runs coincided ($p < 0.05$). We were unable to compare grilse and adult runs in 1990 because grilse were not captured.

In 1985 and 1990, the coho catch rate peaked 3 wks and 8 wks, respectively, after the fall-run chinook salmon catch rate peaked (Table 14).

Steelhead

In all trapping seasons, peaks in the steelhead catch rate coincided with flow increases (Figure 9, Tables 6-12, and Appendix 1). During the 1990-91 trapping season, adult steelhead were caught throughout the entire trapping season. Data collected relating to half-pounders are inconclusive because we believe that the bar spacing in the weir panels and fishtrap did not prevent their movement through the weir.

We were unable to determine the difference in peak runs between the SFTR Weir and any downstream sampling points because the entire length of the steelhead runs were not sampled.

Incidental Species

We caught so few of the following species that our observations are not measurements of run timing:

Spring-run Chinook Salmon Spring-run chinook salmon were sampled in 1986 when the weir was installed during WE August 12 (Figure 10, and Table 8). Average weekly catch rates ranged from 0.0 to 1.4 fish/night through September 1.

Chum Salmon The appearance of chum salmon was highly variable in the four years that they were captured at the SFTR

Weir (Tables 7, 8, 9, and 12). In three of four years (1985, 1987, and 1990), chum salmon were caught in November and December. In 1986, one fish was caught WE September 16.

Brown Trout During the 1990-91 trapping season, a brown trout was captured during WE December 23 (Table 12).

Size of Fish Caught

Fall-run Chinook Salmon

Over the course of this study, fall-run chinook salmon captured at SFTR Weir ranged between 40 and 102 cm FL (Figure 11, and Appendix 2). Length frequency diagrams of fall-run chinook salmon in the weir catch are generally bimodal. Fork lengths of fall-run chinook salmon are presented in Appendix 2).

Scale analysis was used to determine the size separating grilse from adults in all years except 1987. In 1987, we used length frequency analysis to determine the size separating grilse from adults because too few scale samples were collected. Because of their tendency to return as smaller fish, we omitted the fork lengths of known yearling/yearling+ CWT releases from TRH from the total fall-run chinook salmon length frequency (Bill Heubach, Calif. Dept. Fish Game, pers. comm.). The resulting length frequency was smoothed by a running average of three and the location of the nadir between 50 and 60 cm FL was used as the size separating grilse from adults (Figure 12).

The size separating grilse from adults ranged from 52 to 61 cm FL (Tables 4 and 15). Based on these sizes, the percent grilse in the weir catch ranged from 13.5% to 69.3%, and averaged 38.1%.

Coho Salmon

During this study, coho salmon in the SFTR Weir catch ranged from 41 to 85 cm FL, and averaged 61.9 cm FL (Figure 13, and Appendix 3). Fork lengths of coho salmon recovered during the carcass surveys are presented in Appendix 3.

Because of small sample sizes, the sizes separating grilse from adults determined at the Willow Creek Weir for 1984, and 1986 through 1990 were used (Bill Heubach, Calif. Dept. Fish Game, pers. comm.). In 1985, the length frequency distribution of coho salmon trapped at the SFTR Weir was used, based on the nadir between 50 and 60 cm FL, to determine the size separating grilse from adults for 1985.

The size separating grilse from adults ranged from 45 to 59 cm FL (Table 4). Grilse composition in the weir catches ranged from 0% to 75%, and averaged 21.2%.

Steelhead

Steelhead captured at the SFTR Weir ranged from 35 to 83 cm FL and averaged 61.9 cm FL (Figure 14, and Appendix 4). The size separating half-pounders from adults ranged from 40 to 42 cm FL (Table 4). Nearly all the steelhead sampled at the SFTR Weir were adults; a few half-pounders were caught in 1985 and 1990.

Incidental Species

Spring-run Chinook Salmon. Spring-run chinook salmon captured at the SFTR Weir in 1986 ranged from 59 to 71 cm FL, and averaged 65.8 cm FL (Figure 15, and Appendix 2). The size separating grilse from adults was based on Willow Creek Weir data; grilse were ≤51 cm FL (Bill Heubach, Calif. Dept. Fish Game, pers. comm.). All spring-run chinook trapped in 1986 were adults.

Chum Salmon. Chum salmon captured in 1985, 1986, 1987, and 1990 ranged from 57 to 72 cm FL and averaged 67.7 cm FL (Appendix 5). Scale analysis indicated the 1985 catch consisted of 1 grilse and 2 adults and only adults were trapped in the other years.

Brown Trout. The brown trout captured in 1990 was 51 cm FL. A scale sample could not be obtained from this fish because they were too embedded in the skin and could not be removed without causing serious injury to the fish.

Marked Fish Recoveries

External Tags

A number of salmonids bearing external tags were recovered in the SFTR Weir. These observations are compiled in Appendix 6 and should be useful in assessing straying but will not be considered or discussed any further in this report.

Hatchery Straying

Fall-run Chinook Salmon

Hatchery-marked fall-run chinook salmon were captured at the SFTR Weir in all years (Table 16). Ad-marked fish were trapped in all years while other fin clips (Constant Fractional Marking Program [CFMP]-marked) were captured only in 1984 and 1985. The CFMP is described further in Hankin (1982) and Hankin and Diamond (1984). Hatchery-marked spring-run chinook salmon were not recovered in this study.

Heads from Ad-marked fish either captured at the SFTR Weir or recovered during carcass surveys were collected in all years except in 1984. For 1984, we were only able to estimate the total number of fin-clipped fish entering the SFTR basin; we know that at least 21 fish (3 extrapolated CFMP and a count of 18 Ad-marked) entered the SFTR and comprised 28.8% of the weir catch (Table 17).

A total of 25 CWT groups plus 2 CFMP fin clips were recovered in the study (Appendix 7). The percent hatchery fish in weir catches ranged from 3.8% to 23.9%, and averaged 15% (Table 17). Fork lengths of fish captured belonging to all CWT groups are listed in Appendices 8 and 9. Those fork lengths are included in this report as we feel it is important to allow researchers to have readily available access to the data to assess hatchery straying in the Klamath-Trinity River basin.

Hatchery fish straying into the SFTR primarily originated from hatcheries or release sites located within the Trinity River basin, except in 1985 when about equal numbers of strays originated from Klamath River basin release sites and Trinity River basin hatchery/release sites (Table 17). In 1986 and 1987, strays from Trinity River basin hatcheries outnumbered those originating from Klamath River basin hatcheries by a factor of at least 9 to 1. In 1988 through 1990, all of the hatchery fish straying into the SFTR basin originated from Trinity River basin hatcheries.

Except for the 3 fin-clipped fish straying into the SFTR basin in 1985, all of the strays originating from Klamath River basin hatcheries were reared at Iron Gate Hatchery (IGH) and transported to Klamath Glen (295.6 river km downstream of IGH, and 9.5 river km from the Pacific Ocean) for release (Table 17, and Appendix 10).

Strays entering the SFTR basin originated from several Trinity River basin hatcheries or release sites (Table 17, and Appendix 7). Fish released from TRH were recovered in 1984 through 1988, and comprised the majority of the Trinity River basin strays in 1984 through 1987. TRH strays were represented by 7 bicodes composed of 2 yearling+, 4 yearling and 1 fingerling releases, and 1 RV release. The RV program included both fingerlings and yearlings; we were unable to distribute these fish to fingerling and yearlings.

One hundred and twenty seven strays (from the 7 TRH-origin bicodes) entered the SFTR basin between 1984 and 1988. The majority of these were fish released as yearlings or yearling+, comprising 92.7% of the total (Table 18). These 7 bicodes were from brood years (BY) 1982 through 1986 (Table 19, and Appendix 10). During this period, 14 CWT groups (5 fingerling, 6 yearling and 3 yearling+) were released from TRH (Table 18). The majority of the tag groups straying into the SFTR basin were yearling/yearling+ (6 of 7 CWT groups), and only one fingerling CWT group was represented.

We compiled TRH and SFTR return data for all tag groups released from TRH of BY 1982 through 1986 to determine if size-at-release affected straying (Table 19). The total number of fish returning to TRH for all bicodes also was extrapolated from the number of CWT recoveries at TRH. A percent recovery rate was calculated for each bicode: total number of returns (all recovery years) divided by the total number of fish released (Ad-marked and unmarked). An overall recovery rate for each size-at-release was calculated. The ratio of overall recovery rates between size-at-release were compared for each recovery site:

Yearling recovery at TRH :Fingerling recovery at TRH
Yearling+ recovery at TRH :Fingerling recovery at TRH
Yearling recovery at SFTR :Fingerling recovery at TRH
Yearling+ recovery at SFTR:Fingerling recovery at TRH

If, for example, the ratio of yearling:fingerling at TRH was the same as the yearling:fingerling ratio at SFTR, then there would not be any reason to believe that differential straying (with respect to size-at-release) into the SFTR basin occurred. However, if the ratio is higher at SFTR than at TRH, then this is evidence that the relative number of yearlings straying into SFTR was higher than that for fingerlings (i.e., yearlings strayed at a higher rate). The yearling:fingerling and yearling+:fingerling ratios (Table 20) for SFTR were 2.88 and 9.28 times higher than the ratios at TRH; therefore, these data indicate that fish released from TRH as yearlings and yearling+ are more likely to stray into the SFTR basin than TRH fingerling releases.

Fish reared at TRH and released downstream at Lime Point and Steelbridge were recovered in 1985 and 1987 (Figure 1, and Table 17). They comprised a small percentage of the SFTR Weir catch; 1.1% and 0.9% in 1985 and 1987, respectively.

Fish reared at various local hatcheries and rearing ponds (including Hoopa Valley Tribe hatcheries, Horse Linto Creek hatchery, and Cappell Creek rearing pond) strayed into the SFTR basin in 1985 and 1987 through 1990 (Table 17, and Appendix 7). Collectively, they comprised 1.1%, 0%, 2.4%, 10.1%, 9.6%, and 4.0% of the weir catch in 1985, 1986, 1987, 1988, 1989, and 1990. In 1988, twice as many strays from local hatcheries and rearing ponds entered the SFTR basin than strays originating from TRH. In 1989 and 1990, all strays entering the SFTR basin originated from local hatcheries and rearing ponds.

The total number of strays originating from local hatcheries/ rearing ponds was 64 fish, representing 6 CWT groups (Table 21, and Appendix 7). The majority (48 fish) were from a tag group released in Tish-Tang-a-Tang Creek; these fish also were recovered at the highest rate.

In all years of the study, hatchery fish entered the SFTR basin, and presumably spawned with the native stock. Continued hatchery practices such as yearling/yearling+, off-site releases, and yearling releases from rearing ponds would likely result in further mixing of hatchery and native stocks. There is great concern over the genetic consequence of such mixing, and the possibility exists that strays could bring hatchery diseases into the South Fork Trinity River basin.

Coho Salmon

Ad-marked coho salmon were captured in 1985 and 1987 (Table 16). Coho salmon were sampled for CWTs in 1985 only.

We estimate that 39 hatchery-origin coho salmon comprised 35.8% of the weir catch in 1985 (Appendix 7). Hatchery-origin coho salmon entering the SFTR basin in 1985 belonged to three equal-sized tag groups released from TRH, and were part of an experiment to determine if survival is affected by lunar-phase at the time of release (Nishioka et al. 1989). Three of five experimental tag groups released were represented: 24 released 1 d after the full moon, 10 released 2 d after the first quarter, and 5 fish released during the last quarter. Experimental tag groups released from TRH 1 d before, and 1 d after the new moon were not represented.

Nishioka et al (1989) reported that recoveries (combined ocean harvest and TRH returns) of fish released around the new moon ranked highest, and fish released during the last quarter ranked lowest. Fish that were released around the new moon were not recovered in the SFTR basin. While based only on one year's recovery data at SFTR, our data suggests that fish released from TRH during the new moon did not stray.

Sex Ratio

Fall-run Chinook Salmon

Sex ratios for fall-run chinook salmon were determined from 1985 through 1990 (Table 32). Information is not available for 1984 because the carcass survey was halted early (October 31) due to high flows. The sex could be determined from about 99% of the carcasses examined. The carcasses observed were predominantly males including grilse, averaging 71% for the years sampled (range 55.8% to 86.5%). The sex ratio (m:f) averaged 2.53:1, during these years. LaFaunce (1967) reported that the sex ratio was 1.1:1 (95 males:88 females).

Coho Salmon

Sex ratios and for coho salmon were determined from 1985 through 1990 (Table 32). Information is not available for 1984 because the carcass survey was halted early (October 31) due to high flows. Excluding years when carcasses numbered fewer than 3 fish (1986, 1987, and 1989), most of the coho salmon carcasses examined (70.3%) were female; the sex ratio (m:f) was 0.4:1. We are unaware of any previous sex ratio data for coho salmon in the SFTR.

Spawning Locations and Timing

Carcass recovery surveys began in early October and continued through late December. The bulk of the carcass recovery surveys was conducted in the upper section from 1985 through 1988. In 1989 and 1990, effort was more balanced between the upper and lower carcass recovery sections (Appendix 11).

Redds were observed in all years in the lower and upper carcass recovery sections (Appendices 12, 13, and 14). Few redds were observed in 1984; however, this is not a reliable indication of spawning areas because the carcass recovery effort that year was terminated due to high flows and turbid conditions. Redds were observed in Hayfork Creek in all years except 1988 and 1990. Redds were observed in the SFTR as high as RK 49.9 in the mainstem, and RK 5.5 in Hayfork Creek. In 1964, LaFaunce (1967) found that in the SFTR fall-run chinook salmon spawned from the mouth to RK 48.3, and that spring-run chinook salmon spawned upstream of RK 51. It appears that the majority of the redds that we located in the SFTR were found within the fall-run chinook salmon spawning area that LaFaunce (1967) identified. In Hayfork Creek, LaFaunce (1967) found that fall-run and spring-run chinook salmon spawning areas overlapped; fall-run chinook salmon spawned from the mouth to RK 4.3 and spring-run chinook salmon spawned from RK 3.2 to RK 11.3. In this study, redds were found in historical fall-run and spring-run chinook salmon spawning areas.

In the lower carcass survey section, spawning was in progress when carcass recovery surveys began in late October 1988 and 1989. In 1990, spawning began during WE October 28. Spawning was in progress in the upper SFTR carcass recovery section when carcass recovery surveys began in 1986, 1987, and 1989; spawning began either in mid-October or early November in 1985, 1988, and 1990. In general, spawning activity had decreased by mid-December. In all years, and in all carcass recovery sections, peak spawning generally occurred in November. The exception occurred in 1986 in the upper carcass recovery section when peak spawning was observed during WE October 28. The spawning periods observed during the study generally correspond to those reported by LaFaunce (1967) for fall-run chinook salmon in 1984.

Fall-run chinook spawning areas can be broadly identified from the locations of spawned fish recovered during carcass recovery surveys. Spawned fall-run chinook salmon carcasses were recovered in all years in the lower carcass recovery section; spawned fish were recovered in the upper carcass survey section in 1985, 1986, and 1989 (Appendices 15 and 16). Spawned carcasses were recovered in Hayfork Creek in 1986 only.

Historical data for coho salmon distribution in the SFTR is scarce. Local residents reported that coho salmon were observed in the South Fork Trinity River near Hyampom (RK 48.4) (Moffett and Smith 1950). Our recoveries of carcasses near Hyampom indicate that coho salmon continue to utilize roughly the same area; unspawned coho salmon carcasses were found as far upstream as RK 44.7 in 1985 (Appendices 17 and 18). Coho salmon spawning areas could be inferred from the location of spawned fish recovered during carcass recovery surveys. Totals of 3 and 14 spawned coho were recovered in 1985 and 1990, respectively (Appendix 19). Overall, the majority (15 of 17 recoveries) of carcasses were recovered impinged against the weir, suggesting that spawning occurred in the lower river. Spawned coho salmon carcasses were recovered as far upstream as RK 3.2.

A pair of chum salmon were observed spawning about 500 m downstream of the SFTR Weir in 1987.

Prespawning Mortality

Fall-run Chinook Salmon

The female fall-run chinook salmon prespawning mortality was less than 14%, except in 1985 and 1990 when prespawning mortality rates were 71.4% and 50%, respectively (Table 33, and Figure 16). Prespawning mortality rates observed in all years except 1988 are higher than the 1% prespawning mortality rate observed in the SFTR in 1964 (LaFaunce 1967). In 1988, the prespawning mortality rate was 0%, but sample size was small and unreliable (n = 9). Except for 1985, prespawning mortality rates observed in the SFTR basin are lower than those reported for the upper mainstem Trinity River in recent years (1987 and 1988) (Zuspan 1991). Except for 1988, the prespawning mortality rate in the SFTR was generally higher than those observed in the upper Trinity River prior to 1971 (Table 34, and Figure 16). Overall, the in-season prespawning mortality rate observed in the SFTR tended to decrease with time (Table 35), which is consistent with what Zuspan (1991) observed in the upper Trinity River in 1988. It is apparent that prespawning mortality rates in the SFTR basin have increased since 1964 (LaFaunce 1967). We can only speculate as to the reason: 1) drought conditions have lead to increased water temperatures, resulting in stress, 2) hatchery strays have carried disease into the basin, and 3) hatchery fish have hybridized with the native stock causing a general decline in survival.

The low fall-run chinook salmon escapement in subsequent years, age 2 (grilse) in 1987 and age 3 (adults) in 1988, could in part, be attributed to the high prespawning mortality rate observed in 1985.

Coho Salmon

The prespawning mortality rate for female coho salmon averaged 82.6% and ranged from 36.4% to 100% (Table 33). Excluding years when sample sizes were small (less than 10 fish) the prespawning mortality rate was 96.6% and 36.4% in 1985 and 1990, respectively. In comparison, Zuspan (1991) found that the prespawning mortality rate among female coho salmon recovered during carcass surveys in the mainstem Trinity River, between Lewiston Dam and North Fork Trinity River, was 25.6% in 1988. The observed high prespawning mortality rates can be one of the factors responsible for low coho salmon escapements in recent years.

In-season prespawning mortality rates observed for coho salmon in the SFTR basin decreased with time (Table 36). Zuspan (1991) also observed this trend among female coho salmon recovered during carcass surveys in the mainstem Trinity River, between Lewiston Dam and North Fork Trinity River.

The highest recorded prespawning mortality rates for fall-run chinook salmon (71.4%) and coho salmon (96.6%) occurred in the same year (1985). We presume that both species were affected by the same factors.

RECOMMENDATIONS

1. The straying of hatchery-reared fish into the SFTR should be studied in greater detail to assess the impact that hatchery fish may be having on natural production. Where feasible, hatchery practices should be modified to lessen straying.

2. The possibility exists that coho salmon straying and lunar-phase at release may be related. Existing data should be

examined in greater detail to determine if a correlation exists.

3. A quantifiable, non-injurious method needs to be developed to permit field personnel to discriminate spring-run from fall-run chinook salmon. This will allow a better understanding of both populations, particularly where both races overlap in run timing and areas of use.

4. Future attempts to estimate salmon spawner escapements using external tags should include a secondary mark as part of the marking process. Without this secondary mark, fish that had shed their tag would not be counted as a recovery, resulting in an undercount of the tagged fish recovered. The escapement estimate would be overestimated as a result.

5. Future efforts to sample steelhead should consider reducing the bar spacing in the weir panels to sample the half-pounder component.

6. Although the cause of the population decline is unknown, studies should be initiated to assess the possible factors involved. Once these factors are identified, then corrective measures can be taken. One factor we think needs to be addressed quantitatively is the quality of spawning gravels in the South Fork Trinity River basin. Other possible studies include a fish health investigation to determine if the population's decline is related to prespawning mortality, and the presence of hatchery or endemic diseases.

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