Trinity River Tributary Summer Steelhead and Spring Chinook Snorkel Surveys 1990-2014: Canyon Creek, North Fork Trinity River, South Fork Trinity River, and New River

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Abstract: Snorkel surveys for spring Chinook and summer steelhead were conducted between 1990 and 2014 in the four major tributaries to the Trinity River: Canyon Creek, North Fork Trinity River, South Fork Trinity River, and New River. Our analysis showed that tributaries of the Trinity River continued to have more summer steelhead than spring Chinook for the annual sample period 1990 to 2014. The correlation between number of summer steelhead and year sampled was significant and the trend was relatively strong and positive, which suggests that the "population" of summer steelhead in the Trinity River appears to have increased over time. Numbers of summer steelhead from Trinity River tributaries showed a series of three primary oscillating peaks (1991, 2003, and 2012), whereas numbers of spring Chinook were low but they continue to be observed on an annual basis. The correlation between numbers of Spring Chinook and year was not significant and the trend, although positive, was very weak. Composite numbers of spring Chinook showed only two muted peaks over time (1997 and 2012). Annual variation in combined numbers of grilse exhibited one major peek (2011 and 2012) in abundance and there was a significant positive correlation in numbers over time. The pattern of variation in combined numbers of: (1) adult summer steelhead, (2) adult spring Chinook, and (3) grilse from Trinity River tributaries fluctuated considerably on an annual basis from 1990 to 2014. In Canyon Creek, although correlation analysis showed a significant negative correlation between survey year and numbers of summer steelhead and even through the correlation with year was negative for spring Chinook, it was not significant. Canyon Creek was the only tributary where species annual patterns of abundance were significantly and positively correlated, which suggests that this concordant trend represents declining populations of both species of salmonids in this tributary. For the North Fork Trinity River, even though there appeared to be a slight annual increase in number fish for both summer steelhead and spring Chinook, the trend was not significant for either species. For the South Fork Trinity River numbers of summer steelhead increased significantly between 1990 and 2014; whereas, although numbers of spring Chinook continue to fluctuate, they were not significantly correlated with year. For New River, annual survey results indicated a significant positive correlation between survey year and number of both summer steelhead and spring Chinook. It appears that populations of both salmonids have increased significantly from 1990 to 2014. Fluctuations in annual patterns of abundance were largely not concordant between: (1) species, (2) within adults of each taxon, or (3) among tributaries, which attests further to the variation and uniqueness of environmental conditions associated with these unique tributaries.

Key words: snorkel survey, tributary, steelhead, Chinook, Canyon Creek, North Fork Trinity River, South Fork Trinity River, New River.

INTRODUCTION

The Trinity River, located in northwestern California, is 165 miles long, drains 2,853 square miles, and is the largest tributary to the Klamath River [(1)]. Construction of the Trinity and Lewiston dams in 1958 reduced the length of anadromy to 113 river miles, which includes four major tributaries (**Figure 1**): Canyon Creek, North Fork Trinity River, South Fork Trinity River, and New River [(2)]. These are wild and undammed tributaries that support two species of salmonid with unique life history traits requiring adults to migrate into tributaries during spring and early summer to remain until spawning in the fall and winter.

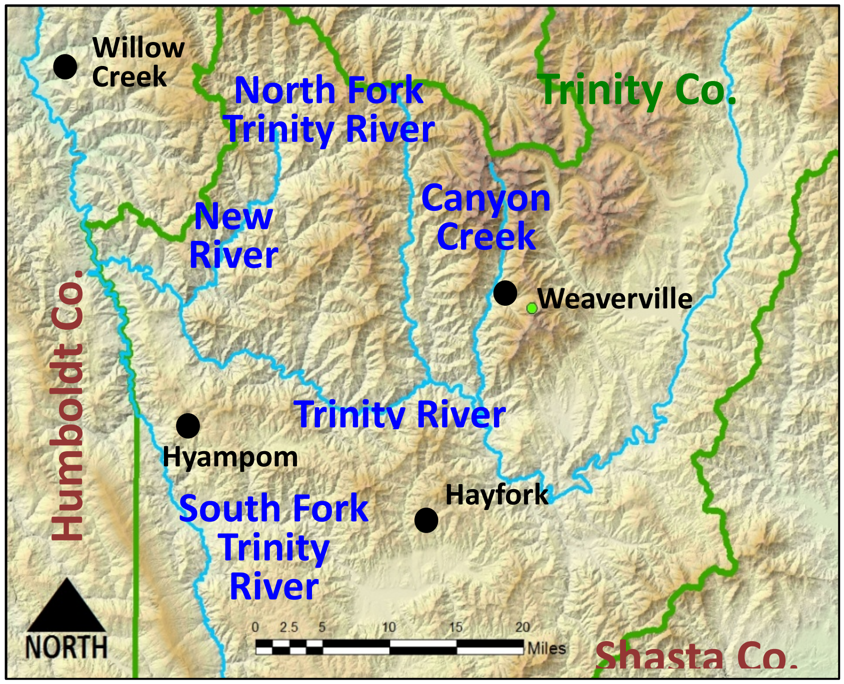

Figure 1. Map of tributaries of Trinity River that were sampled in snorkel survey.

One of these species is the steelhead (*Oncorhynchus mykiss*), whose population is defined by the Klamath Mountain Province Steelhead Evolutionary Significant Unit (ESU) [(3, 4)]. The ESU includes summer, fall, and winter runs of steelhead in the Klamath River north to the Elk River, Oregon [(3, 4)]. The other is the Chinook (*Oncorhynchus tshawytscha*), whose population is defined by the Upper Klamath-Trinity River ESU, which includes both spring and fall run Chinook in the Klamath-Trinity basin[(3, 4)].

The over-summering population of steelhead is called the "summer steelhead" and the over summering population of Chinook is called the "spring Chinook." Although these populations have unique life history traits compared to those found throughout the Klamath and Trinity basins, genetic information has not demonstrated significant genetic differences to define these populations as distinct species ESU's [(3, 4, and 5)]. Spring Chinook were divided into two categories: (1) adults that were estimated to be >22 inches in length and (2) grilse less than that. Grilse Chinook are two year old fish, typically males, and adults are three to six years old fish with the bulk of adults in the three to four year age class.

We divided summer steelhead into two categories: (1) adults >16 inches in length and (2) half pounders that were less than that. Half pounder steelhead are those that migrate to the ocean for less than one year before returning to fresh water and are most commonly associated with fall steelhead(3). For the purpose of this report half pounder steelhead are not included due to confusion with large resident trout. Population surveys have been attempted sporadically beginning in 1963 and data for this report has been collected in the four tributaries since 1990 in an effort to enumerate population trends of summer steelhead and spring Chinook.

Study Area

Canyon Creek

Headwaters of Canyon Creek begin on the south face of Thompson Peak (9,002 ft.) and drain in a southerly direction for approximately 22 miles before joining the Trinity River near Junction City, California (1,497 ft.). The upper 11 miles are completely within the Trinity Alps Wilderness Area. Anadromous fish have access to approximately 15 miles of the creek before a large water fall prevents upstream migration. The entire area below the water fall encompasses the length of the snorkel survey when conditions are suitable.

Historically, Canyon Creek had hydraulic mining along the lower 13 miles and there were two dams that diverted most of the creek’s summertime flow to flumes and ditches. Currently no hydraulic mining or dams exist within the watershed. Suction dredging was common in this tributary until the 2009 until a moratorium on suction dredging was enacted in 2009.

North Fork Trinity River

Headwaters of the North Fork Trinity River begin on the north face of Thompson Peak (9,002 ft.) and drain in a southerly direction for approximately 28 miles before joining the Trinity River near Helena, California (1,394 ft.). The North Fork Trinity River is unique in that most of the watershed is located entirely within the Trinity Alps Wilderness, thus affording it a high degree of protection from human development.

No extensive mining operations, logging, or dams were ever constructed in this tributary, although historically there was placer mining in the river. Summer steelhead regularly have access to at least 22 miles of the North Fork Trinity River and no barrier to migration has been identified for them other than low flow above the confluence with Grizzly Creek.

Annual surveys generally covered the 22 river miles below the confluence of the North Fork with Grizzly Creek due to low streamflow conditions above it. Spring Chinook were usually confined to the lowest reach of the North Fork near Blacks Flat, except during years with exceptionally high summer flows, which allows access above by these larger fish to a series of waterfalls. The survey includes two reaches on the East Fork of the Trinity River, one on Rattlesnake Creek, and six on the North Fork Trinity River for a total of 31.5 river miles. Low water conditions often make it not necessary to survey the East Fork Trinity River or Rattlesnake Creek. The East Fork of the North Fork Trinity River is the biggest tributary and represents just over 30% of the entire North Fork Trinity River watershed in terms of acreage but remains unimportant in terms of adult summer fish use.

Figure 2. Snorkel survey in the Canyon Creek tributary.

South Fork Trinity River

Headwaters of South Fork Trinity River watershed begins in the North Yolla Bolly Mountains (4,460 ft.) and drain in a northerly direction for approximately 92 miles before joining the Trinity River near Salyer, California (460 ft.). It is the largest tributary to the Trinity River and is historically known for its dense timber and bountiful salmon population. The South Fork Trinity River is California’s longest undammed river and has received less mining than the other tributaries due to its relative lack of gold. After World War II, large machinery made possible large scale logging and road construction in the watershed, and by 1964 the basin had been heavily logged and riddled with roads.

In 1964 a rain-on-snow event resulted in a significant erosive flood peaking at an estimated 95,600 cubic feet per second and washed enormous quantities of sediment into the river from the destabilized hillsides decimating aquatic populations and salmon habitat [6, 9]. Before the great flood, runs of spring Chinook were estimated to be between 7,000 and 10,000 in 1963[7] and 11,600 in 1964[8]; however, the population in this tributary has failed to recover to those previous historic levels.

In 1972, the lower 55 river miles became officially designated as a Wild and Scenic River. The survey includes 15 reaches on the South Fork Trinity River one reach on the East Fork of the South Fork of the Trinity River for a total of 81.5 river miles. Hayfork Creek has often been surveyed at the same time, but low water flows and water clarity have resulted in it being surveyed separately. Hayfork Creek and the East Fork of the South Fork Trinity River are the two major tributaries to the South Fork Trinity River. Both tributaries historically had robust salmon runs, but degradation as a result of unregulated logging and road construction has impacted them significantly. Additionally, Hayfork Creek typically has low water quality and high temperatures during summer months making it a challenge for salmonid populations that have evolved an over-summering life history strategy.

New River

Headwaters of New River are located within the Trinity Alps Wilderness area and drain south for approximately 21.4 miles before joining the Trinity River near Burnt Ranch, California (700 ft.). Naming of this river is unique compared to other rivers because it begins at the confluence of Virgin and Slide creeks. The upper 97,800 acres of the watershed are within the wilderness area, and the lower 21 miles were included into the National Wild and Scenic River system in 1980. No dams were ever constructed in the New River although extensive placer and hard rock mining have occurred historically. Slide Creek was named because it was diverted into a long water slide for mining purposes during the late 1800’s and early 1900’s. A few mining towns in the upper watershed were established during the 1880’s, which were mostly abandoned by the 1920’s. Even with establishment of these boom and bush mining operations, the rugged remoteness of the watershed has kept most of it free of large logging operations and there are fewer people living there today than there were in 1900. The survey includes seven reaches on the New River, two reaches on the East Fork of the New River, two reaches on Virgin Creek, one reach on Eagle Creek, and one reach on Slide Creek for a total of 31.6 miles of river. This basin supports the most robust population of summer steelhead in the basin. The largest tributary to the New River is the East Fork of the New River, Virgin Creek, and Slide Creek.

METHODS

Survey Design

The anadromous zone of each tributary was broken into 3- to 7-mile reaches based on accessibility and logistics involving driving, hiking, or combination thereof. Most sampled reaches were consistent from 1990 to 2014, but some have been divided further, whereas others have been combined. Surveys were scheduled for similar weeks in August every year based on previous studies and the assumption that summer steelhead and spring Chinook have migrated into the basin to over summer. Fish counted included; ½ pounders (16 inch steelhead), adult steelhead (>16 inches), adult Chinook (>22 inches), and grilse Chinook (<22 inches).

Training

Pre-survey safety meetings were held to discuss hazards and how to prepare for each survey were made before each dive day. New surveyors were trained in identification of juvenile and adult fish by individuals with prior experience working in fisheries within the Trinity Basin from a wide number of government, non-profit, and tribal agencies. Typically annual South Fork Trinity River surveys were coordinated by California Department of Fish and Wildlife (CDFW), whereas surveys of all the other tributaries were coordinated by the U.S. Forest Service (USFS).

Sampling Technique

Teams of from 2 to 4 divers begin at a designated upstream limit of a reach and continued downstream until a designated end of the reach. Survey crews hung visible flagging at the beginning of each survey so that upstream teams surveying down would know where to end their survey. Inexperienced divers were placed on teams with experienced divers for safety purposes and salmonid identification quality assurance. When deep pools were encountered, divers swam parallel to each other for full coverage. At the end of a pool, and periodically during the survey, divers regrouped and discussed observations to reach agreement regarding the number of each species of fish observed.

Statistical Analysis

For all surveys, annual trends in mean number of fish observed were represented by μ. All pairwise correlations between year and annual numbers of summer steelhead and spring Chinook assessed by use of regression analysis (combined samples only) and Spearman's Rank correlations analysis (r_s). The Shapiro–Wilk test (W) was used to test the null-hypothesis that sample

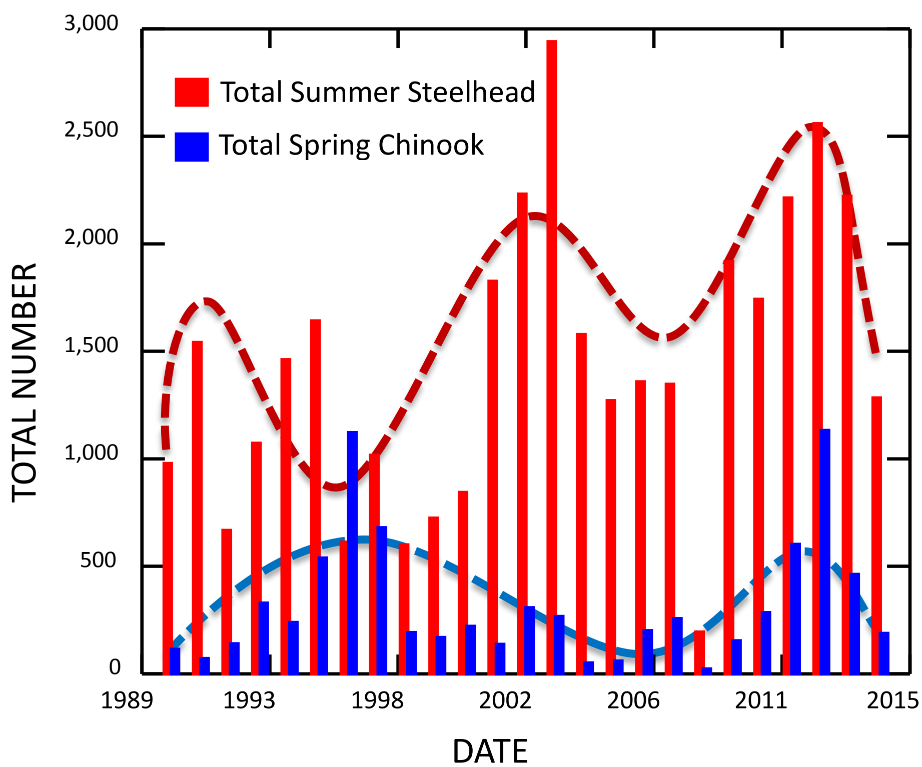

Figure 3. Variation in total numbers of summer steelhead and spring Chinook for sample period 1990 to 2014. Dashed red and blue lines are 6th degree polynomial trend lines for both species, respectively.

size of summer steelhead and spring Chinook came from normally distributed populations[1].

RESULTS

Information used in this annual assessment of snorkel survey data was collected from 1900 to 2014 (**Appendix A**). These data included: (1) total numbers of fish, (2) species designation, and (3) identification of the specific tributary sampled. Data used in subsequent statistical analyses herein are found in **Appendix B** and **Appendix C**. Basic statistics for each set of species at each sample location are provided in **Appendix D** for adult fish and **Appendix E** for grilse. Spearman's Rank pair-wise correlation statistics (2-tailed *p*-values) between: (1) total numbers of fish observed on an annual basis, as well as (2) between each species and its sampled tributary are provided in **Appendix F**. Data sets for summer steelhead and spring Chinook specific to each tributary are provided in **Appendix G** and **Appendix H**, respectively.

Combined Samples of Summer Steelhead and Spring Chinook

Variation in numbers of summer steelhead and spring Chinook in all tributaries combined fluctuated considerably on an annual basis between 1990 and 2014 (**Figure 3**). Overall, tributaries of the Trinity River had more summer steelhead than spring Chinook for the survey interval. Combined observations of summer steelhead (n = 35,828, μ = 1,433.1) were considerably larger than those obtained for spring Chinook (n = 9,133, μ = 365.32) (**Appendix D**); and there was a significant positive correlation between the total number of summer steelhead ($r_s = 0.603$, $p = 0.001$, $n = 23$) and the annual survey from 1990 through 2014, but there was no such relationship ($r_s = 0.321$, $p > 0.05$, $n = 23$) for spring Chinook for the same sample period (**Figure 3**, **Appendix F**).

Additionally, there was no significant correlation ($r_s = 0.318$, $p > 0.05$, $n = 23$) in the osculating, yet a-synchronous annual pattern of seasonal variation in numbers of fish counted between summer steelhead versus spring Chinook (**Figure 3**).

For combined numbers of summer steelhead the 6^{th} order polynomial trend line showed a series of three primary oscillating peaks centered around 1991, 2003, and 2012, with significantly increasing total numbers of summer steelhead moving forward in time on an annual basis. In contrast, total combined numbers of spring Chinook showed a more muted oscillation of only two peaks centered on 1997 and 2012. These data clearly show that the patterns of annual variation in combined numbers of summer steelhead and spring Chinook from Trinity River tributaries are not in synchrony.

For example, for the sample interval 1990 to 2014, summer steelhead showed peak numbers in 2002 (6.2%, n = 35,828), 2003 (8.2%), 2011 (6.2%), 2012 (7.1%), and 2013 (8.2%); whereas, the largest

[1] If the *p*-value is less than the 0.05, then the null hypothesis is rejected and there is evidence that the data tested are not from a normally distributed population. Conversely, if the *p*-value is >0.05, then the null hypothesis that the data came from a normally distributed population cannot be rejected.

samples of spring Chinook were observed in 1995 (7.5%, *n* = 9,133), 1996 (12.3%), 1997 (7.4%), 2011 (10.9%), 2012 (13.8%), and 2013 (6.1%).

Further, although the lowest numbers of summer steelhead were observed in 1992 (1.9%), 1996 (1.7%), 1998 (1.7%), and 2008 (0.5%), the lowest numbers of spring Chinook were counted in 1991 (0.8%), 2004 (0.8%), 2005 (0.8%), and 2008 (0.3%).

Regression analysis was used in an effort to determine whether annual sampling was useful in assessing trends in total numbers of fish for both summer steelhead and spring Chinook. For summer steelhead, the correlation (Multiple R) between total number of fish sampled and date was 0.428, which accounted for 18.3% of the annual variation in counts (**Figure 4**). Analysis of variance (ANOVA) indicated that although significant (F = 5.159, p = 0.032, df = 1), the linear relationship between annual counts of summer steelhead and year of survey was weak for predicting an upward trend in numbers of fish, which suggested that although that the independent variable (year of sample) helps to explain some of the variation in the dependent variable (total number of fish), it clearly does not account for much of it.

For spring Chinook, the Multiple R was 0.199, which only accounted for 4.0% of the annual variation in total number of spring Chinook counted (**Figure 4**). As expected, the ANOVA was not significant (F = 0.310, p = 0.582, df

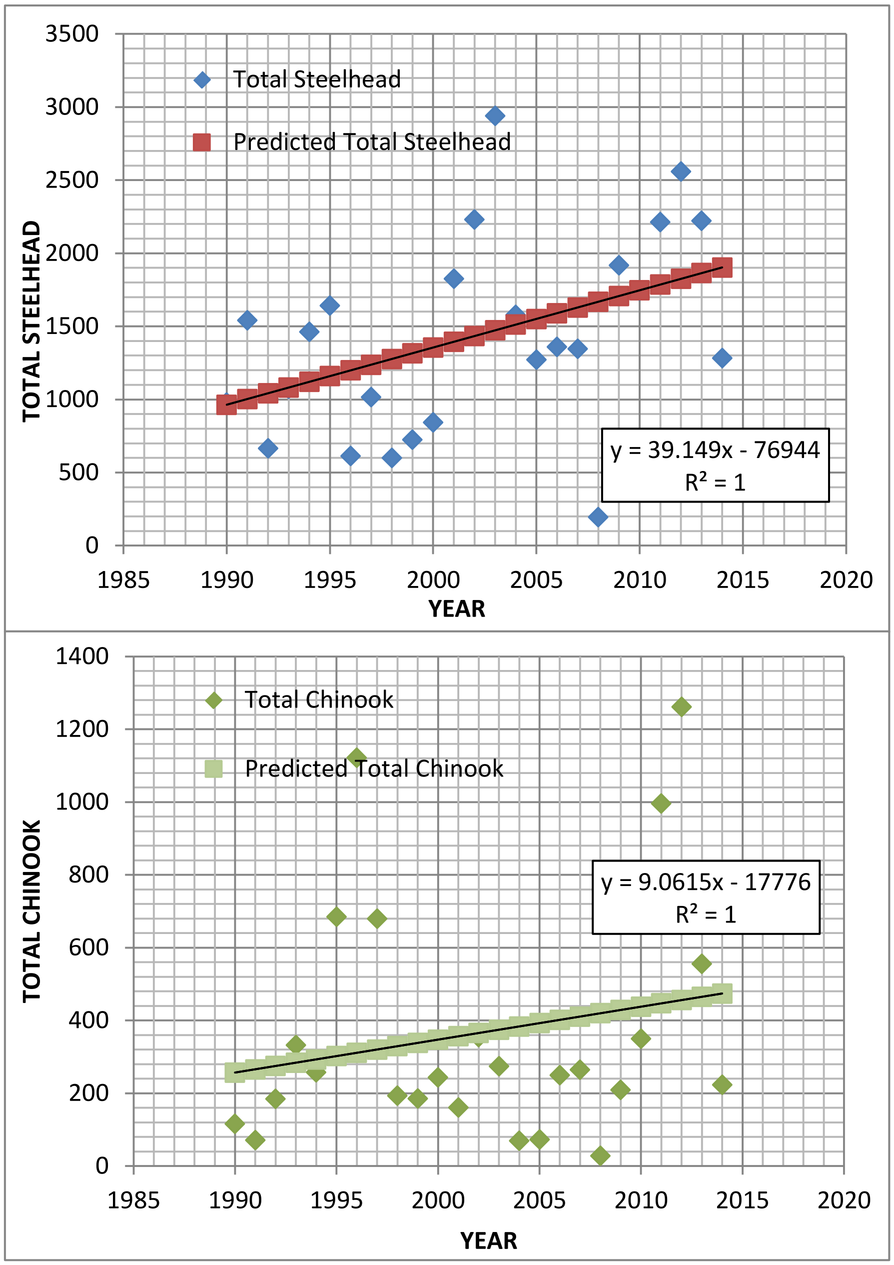

Figure 4. Linear regression of total number of fish counted and year of sample for steelhead and spring Chinook, which attempted to detect and depict any potential upward or downward trend in annual numbers of fish over time.

= 1), indicating that there was no linear relationship between annual counts of spring Chinook and year of survey. Thus, for spring Chinook an annual trend in total numbers of fish is not readily apparent.

Sample Size of Summer Steelhead and Spring Chinook

We tested the null hypothesis that the number of fish in composite samples of from all tributaries for both steelhead and Chinook were normally distributed over the sample period. Results showed that the sample size of summer steelhead was normally distributed (W = 0.982, p = 0.928, n = 25), but sample size of Chinook exhibited a distribution that was significantly non-normal (W = 0.792, p = 0.000, n = 25) (**Appendix D** and **Figure 5**) [2].

In addition, sample size was also normally distributed in summer steelhead from the: (1) North Fork Trinity River and (2) New River. These two tributaries also had the largest number of fish observed over the sample period (**Appendix D**). However, all summer steelhead and all spring Chinook from all of the other tributaries showed a significant non-normal pattern in sample size, including spring Chinook from the South Fork Trinity River, which was characterized by the largest composite annual sample of spring chinook, relative to all other tributaries (**Appendix D**).

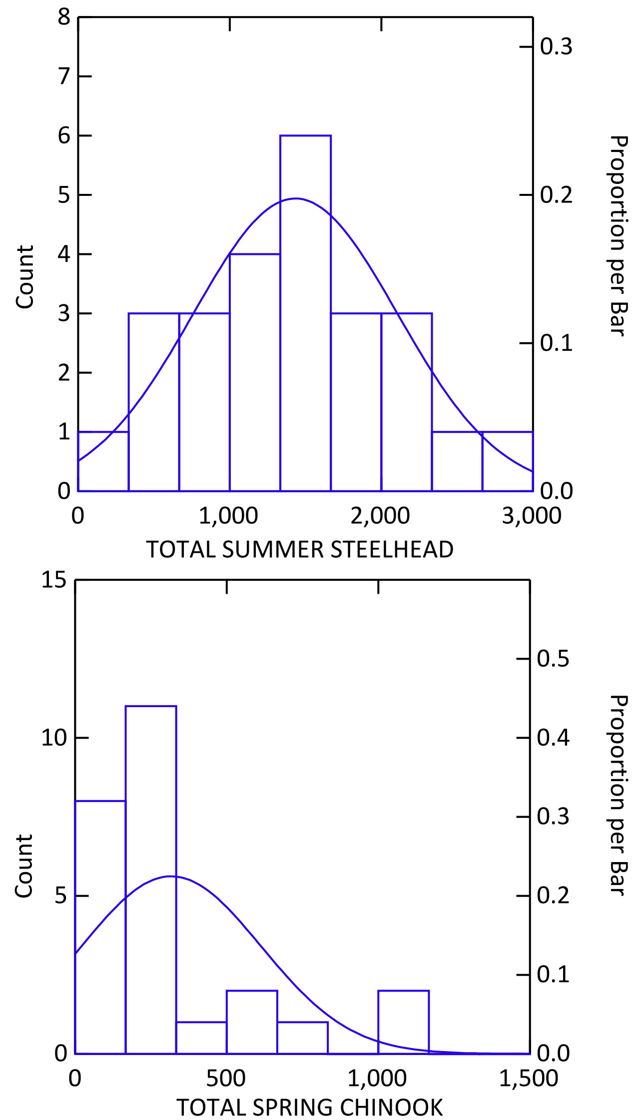

Figure 5. A Shapiro-Wilk test (*W*) used to test for normality in the overall distribution of group size of the samples for steelhead and Chinook.

Individual Samples of Steelhead and Chinook

Summer Steelhead

As indicated, there are four major tributaries associated with the upper Trinity River, which combined have higher annual numbers of summer steelhead than spring Chinook, with the New River (n = 18,975, μ = 759.0) and North Fork of the Trinity River (n = 15,250, μ = 635.4) contributing 53.0% and 42.6% of the combined sample, respectively (**Appendix D**). In addition to the significant positive ($r_s < 0.05$) annual trend in combined numbers of summer steelhead for the tributaries (**Appendix F**), data collected for the

[2] A log transformation of the combined spring Chinook dataset helped in moving the distribution toward normality (i.e., W = 0.034, p = 0.525), but it did not help the regression analysis (Multiple R = 0.142, R-square = 0.020 [i.e., 2.0% of the variation accounted for]).

South Fork Trinity River and New River tributaries also showed significant positive increases in numbers of fish sampled over time, ($r_s \geq 0.674$, $p \leq 0.001$, $n = 23$) and ($r_s \geq 0.787$, $p \leq 0.001$, $n = 23$), respectively. In contrast, summer steelhead from the Canyon Creek tributary exhibited a significant negative ($r_s = -0.443$, $p = 0.050$, $n = 23$) correlation with year sampled (**Figure 6** and **Appendix F**). Even though **Figure 3** showed a series of three primary oscillating peaks centered around 1991, 2003, and 2012 with increasing total numbers of summer steelhead, only the: (1) North Fork Trinity River and New River, and (2) South Fork Trinity River and New River showed significant ($p < 0.05$) synchronous patterns in their annual survey counts among the four primary tributaries of the Trinity River.

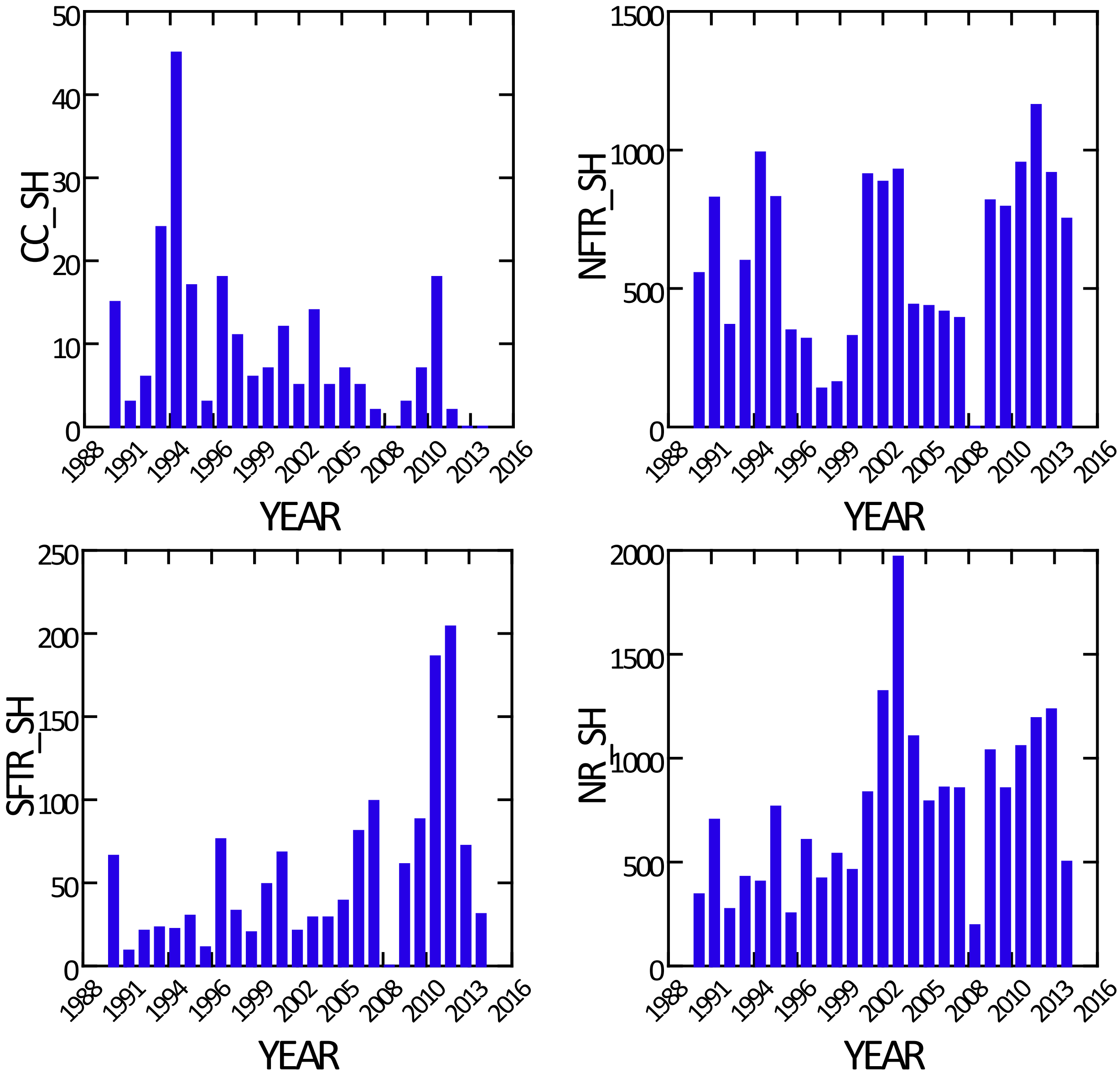

Figure 6. Annual variation in numbers of summer steelhead from Canyon Creek (CC), North Fork Trinity River (NFTR), South Fork Trinity River (SFTR), and New River (NR) for the sampling period 1990 to 2014.

Spring Chinook

For spring Chinook, the South Fork Trinity River (*n* = 6,649, *μ* =266.0) and New River (*n* = 2,137, *μ* = 85.5) tributaries contributed 72.8% and 23.4% of the combined sample, respectively (**Appendix D**). Although there was no significant annual trend in combined numbers of spring Chinook, data collected for the New River tributary showed a significant positive (r_s = 0.628, *p* = 0.010, *n* = 23) increase in numbers of fish sampled from 1990 through 2014 (**Figure 7** and **Appendix F**). Further, annual patterns of variation in numbers of spring Chinook showed two major oscillations, one occurring in 1996 and the other in 2012 (**Figure 3**).

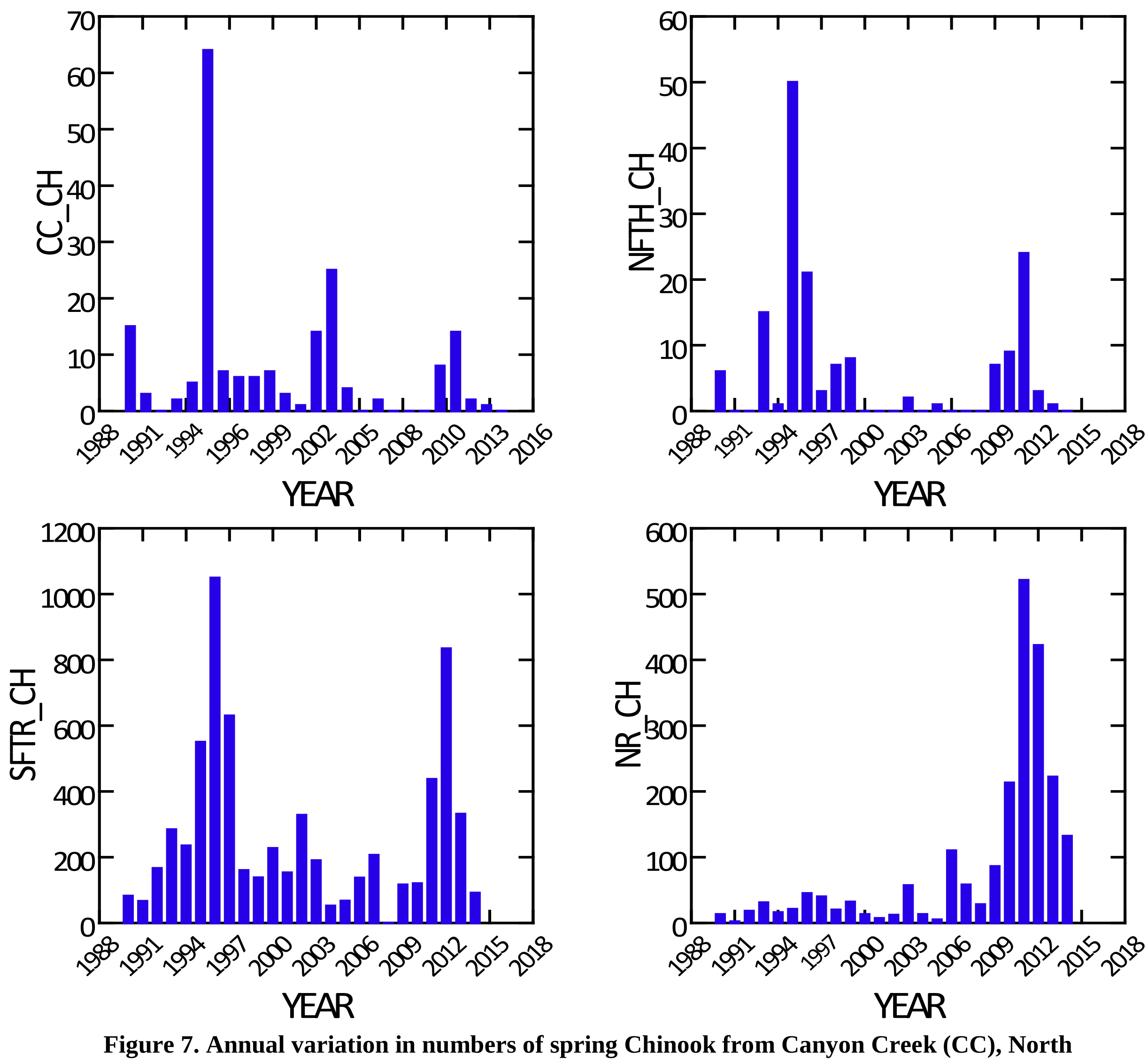

Figure 7. Annual variation in numbers of spring Chinook from Canyon Creek (CC), North Fork Trinity River (NFTR), South Fork Trinity River (SFTR), and New River (NR) for the sampling period 1990 to 2014.

Annual variation in total numbers of spring Chinook showed increases in 1995 through 1997, and 20011 through 2013, with the largest increases occurring in 1996 and 2012; major reductions in numbers were observed in 1991, 2004, 2005, 1991, and 2008.

Grilse

Variation in numbers of grilse showed a significant positive correlation (r_s = 0.571, p = 0.010, n = 25) over the sample duration from 1990 to 2014 when samples from all tributaries were combined (**Figure 8**). The South Fork Trinity (n = 617, μ =32.5) and the New River (n = 521, μ = 32.6) tributaries accounted for 51.3% and 43.3% of the combined sample, respectively (**Appendix C** and **Appendix E)**.

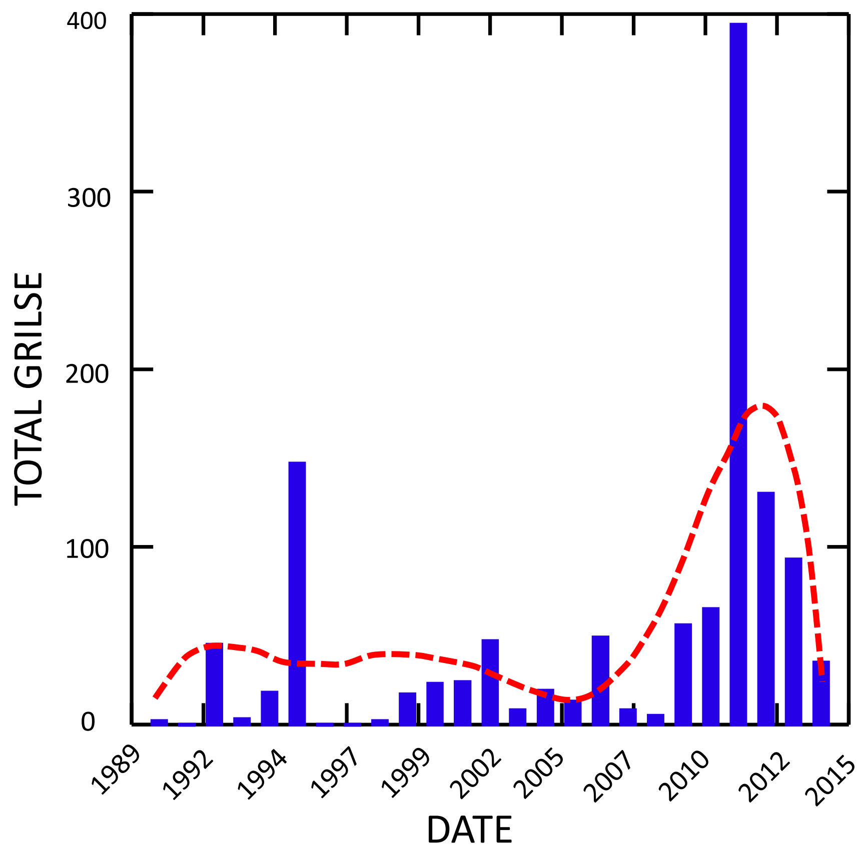

Figure 8. Annual variation in combined counts of grilse for the four Trinity River Tributaries, sampling period 1990 to 2014. Dotted red line represents the 6th degree polynomial trend line for count data.

Small increases or "pulses" of between 45 and 93 fish occurred in 1992, 1996, 2009, 2010, and 2013, with the largest increase occurrring in 2011 (n = 394). The polynomial trend line showed only one major peek (2011-2012) in the annual sampling sequence from 1990 to 2014.

Grilse from the Sorth Fork Trinity and New River tributary were significant and positively correlated in their annual flucutation in total numbers of fish (r_s = 0.442, p = 0.050, n = 15), but because of the conspicuous absence of fish in Canyon Creek and the North Fork Trinity River tributaries, similar comparisons were not possible (**Figure 9**). Clearly, the South Fork Trinity River and New River are the primary drivers of annual variation in Trinity River tributaries for grilse.

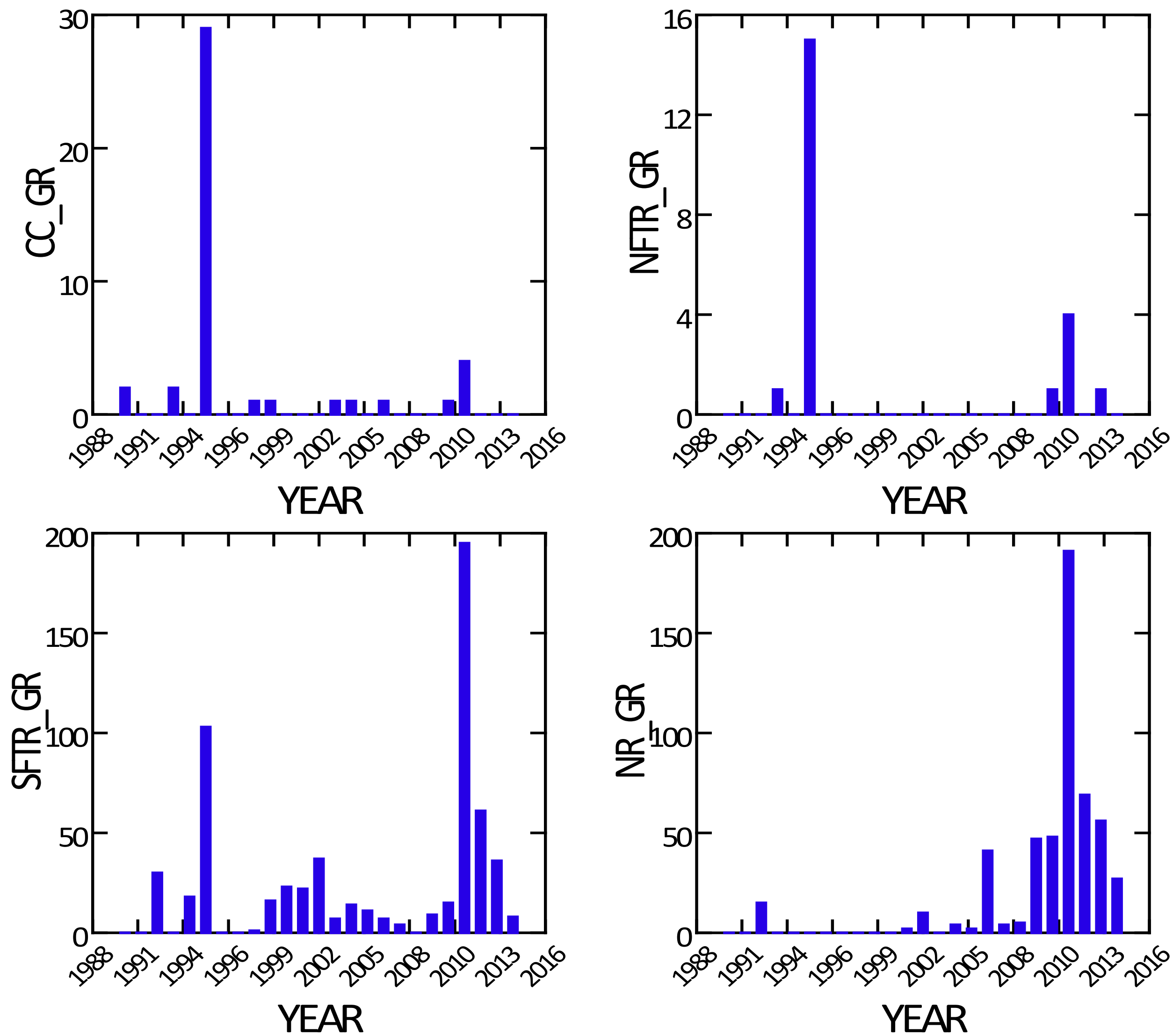

Figure 9. Annual variation in numbers of grilse from Canyon Creek (CC), North Fork Trinity River (NFTR), South Fork Trinity River (SFTR), and New River (NR) for the sampling period 1990 to 2014.

Trinity River Tributaries

Canyon Creek

Canyon Creek was usually the first tributary to be snorkeled in August. This tributary had the least number of summer steelhead (n = 235, μ = 9.8) and the second smallest number of spring Chinook (n = 189, μ = 7.6) compared to the other three tributaries (**Appendix D**, **Figure 6,** and **Figure 7**). Although correlation analysis showed a significant negative correlation between survey year and numbers of summer steelhead ($r_s = -0.443$, $p = 0.050$). For spring Chinook, even though this relationship was negative it was not significant ($r_s = -0.235$, $p > 0.050$). Canyon Creek was the only tributary where their annual patterns of abundance were significantly and positively correlated ($r_s = 0.451$, $p = 0.050$), which suggests to us that this concordant trend represents declining populations of both species of salmonids in this tributary (**Appendix F**).

For summer steelhead the largest numbers of fish recorded occurred in 1993, 1994, 1995, 1997, and 2011; whereas, major declines were observed in 1991, 1996, 2007, 2008, 2009, 20012, and 2013. Peak numbers of spring Chinook occurred in 1995 and 2003, and no fish were observed in 1992, 2001, 2005, and 2007 through 2009, 2013 and 2014.

North Fork Trinity River

North Fork Trinity River was usually the second tributary to be snorkeled in August. In the lowest survey of this reach there are a series of waterfalls that have historically limited spring Chinook passage but do not pose an obstacle to summer steelhead. This river averages 635.4 (n = 15,250) summer steelhead and 6.3 (n = 158) spring Chinook per (**Appendix D, Figure 6,** and **Figure 7**). Although there appeared to be a slight increase in number of summer steelhead for the period spanning 1999 through 2014, the trend was not significant ($r_s = 0.312$, $p > 0.050$) (**Appendix F**). Similarly, although there appeared to be a slight decline in numbers of spring Chinook between 1990 through 2014, the trend also was not significant ($r_c = -0.026$, $p > 0.050$).

Counts peaked for summer steelhead in 1994, 2001, 2003, 2001, 2012, and 2013; and major declines in numbers of fish were associated with 1998 and 1999. In contrast, spring Chinook followed a different annual pattern with the largest number of fish occurring in 1993, 1995, 1996, and 2011; no fish were observed in 1991, 1992, 2000, 2001, 2002, 2004, 2006 through 2008, and 2014. There was no significant correlation ($r_s = 0.032$, $p > 0.050$, $n = 23$) in the annual pattern of abundance between these two species in the North Fork Trinity River tributary (**Appendix F**).

South Fork Trinity River

South Fork Trinity River was usually the third tributary to be snorkeled and typically had the greatest abundance of spring Chinook of all the tributaries (**Figure 10**). It is the only Trinity River tributary with greater numbers of spring Chinook (n = 6,649, $\mu = 265.96$) than summer Steelhead (n = 1,368, $\mu = 57.0$) (**Appendix D, Figure 6,** and **Figure 7**). Numbers of summer steelhead increased significantly ($r_s = 0.674$, $p = 0.001$) between 1990 and 2014 (**Appendix F**); whereas, although numbers of spring Chinook continue to fluctuate, they were not significantly correlated with the year in which they were surveyed ($r_s = 0.065$, $p > 0.050$).

For summer steelhead the peak counts occurred in 2011 and 2012, with the lowest numbers recorded in 1991 and 1996. In contrast, peak counts of spring Chinook occurred in 1996, 1997, and 2012; with the smallest number of fish recorded in 1990, 1991, 2004, 2005, 2008, and 2014. There was no significant correlation ($r_c = 0.133$, $p > 0.050$, $n = 23$) between summer steelhead and spring Chinook in annual pattern of abundance for the South Fork Trinity River tributary.

New River

New River was usually the last tributary to be snorkeled in August and typically had the greatest abundance of summer steelhead (n = 18,975, μ = 759.0) and second greatest abundance of spring Chinook (n = 2,137, μ = 85.48) among all the tributaries (**Appendix D, Figure 6,** and **Figure 7**). Annual survey results indicated a significant positive correlation between survey year and number of both summer steelhead (r_s = 0.787, p = 0.001) and spring Chinook (r_s = 0.628, p = 0.010) (**Appendix F**). It appears that populations of both runs of salmonids in the New River have increased significantly from 1990 to 2014. Peak numbers of summer steelhead were observed in 2002 through 2004, 2009, and 2011 through 2013; major declines were observed in 1992, 1996, and 2008. New River saw peak numbers of spring Chinook in 2006, and 2010 through 2014; but few fish in 1991, 2001, and 2005. The correlation between annual numbers of summer steelhead and spring Chinook was not significant (r_c = 0.367, p > 0.050, n = 23).

Annual Patters of Abundance in the Tributaries

For summer steelhead that were statistically significant patterns of annual abundance between populations observed in: (1) the North Fork Trinity River and New River and (2) in the South Fork Trinity River and New River. For spring Chinook significant patterns of annual abundance occurred in: (1) Canyon Creek and the North Fork Trinity River, (2) the North Fork Trinity River and New River, and (3) the South Fork Trinity River and New River. Concordant patterns of annual abundance between summer steelhead and spring Chinook were only observed in the Canyon Creek tributary.

DISCUSSION

For all Trinity River tributaries combined, over-summering salmonid populations were low in numbers, and are likely below minimum viability for these unique populations. This indicates that the survival of these populations, in absence of human intervention, is uncertain based on the vagaries of random and inevitable changes in population demographics, population genetics, environmental and climatic changes, anthropocentric modification of watersheds, as well as potential and unforeseen natural disasters [(10)].

Existence of these anadromous salmonids is dependent upon a number of factors, some of these factors include: (1) favorable ocean conditions, (2) ability to migrate to and from the ocean, (3) abundant cold water during the summer months, and (4) ability to spawn and rear successfully. As such, the large numbers of factors directly and indirectly affecting these populations make it difficult to identify specific causes of the population trends reported herein. Additionally detailed studies of the hydrology and geomorphology, and ecological characteristics of these tributaries are warranted.

Quality and quantity of the hydrograph in each of these free flowing tributaries is related to the snow pack, rainfall, spring input, tributary input within each watershed, timber harvesting and extent of use and degradation, particularly in the headwaters, as well as a number of other environmental factors.

Flow regimes vary from year-to-year in each of tributary and often not all reaches are surveyed each year due to the fact that there is too little flow to support over summering fish. Such was the situation in 2014 when Canyon Creek was not surveyed because of low flow and warm water. Further, reaches or entire tributaries are occasionally not surveyed due to logistical constraints, marijuana enforcement, or wildfire activity.

Summer Steelhead, Spring Chinook, and Grilse

Our analysis showed that tributaries of the Trinity River continued to have more summer steelhead than spring Chinook for the annual sample period from 1990 to 2014. The trend in abundance of summer steelhead was significant, comparatively strong, and positive, which suggests that the "population" of summer steelhead in the Trinity River, as a composite of the Trinity River tributaries, appears to have increased and is moving forward in time on an annual basis. Numbers of spring Chinook in tributaries of the Trinity River are historically low, but they continue to be observed on an annual basis. Although the correlation between numbers of Spring Chinook and year was positive it was not significant. Annual variation in combined numbers of grilse showed a significant positive correlation with year sampled, but they are primarily associated with the South Fork Trinity River and New River.

In addition, we show clearly that the pattern of variation in combined numbers of: (1) adult summer steelhead, (2) adult spring Chinook, and (3) grilse from Trinity River tributaries fluctuated considerably on an annual basis from 1990 to 2014. Only South Fork Trinity River summer steelhead, New River summer steelhead, and New River spring Chinook exhibited a significant positive correlation with year for the sample period 1990 through 2014.

In contrast, annual counts of summer steelhead from Canyon Creek showed a significant negative correlation with annual sampling, and although the relationship between year and numbers of spring Chinook was not significant, the concordant negative trend in both species is characteristic of populations that are in decline; which is also reflected in the fact that the annual pattern of population decline in these two species was significantly correlation, a pattern not seen in any other pair of sympatric species combinations in the other three tributaries.

Effects of Size of Sample

Our analysis clearly showed that sample size was normally distributed for combined annual summer steelhead, and for summer steelhead populations from the North Fork Trinity and New River tributaries that historically have yielded large runs, but not for combined numbers of spring Chinook, or any other species in any other tributary. That mostly small groups of individual summer steelhead and spring Chinook use only some tributaries and not others is likely the result of spatial, hydrological, geomorphologic, ecological characteristics, and other constraints associated with small-sized tributaries in general, relative to the much larger spatial, hydrological, and geomorphological dynamics of the Trinity River proper. These observations are particularly relevant in delineating management options of Chinook in tributaries with respect to: (1) expectations for populations size, (2) production, (3) long-term viability,

(4) habitat enhancement, (5) conservation, and (6) overall use relative to more “tributary adapted” summer steelhead.

Tributaries

Steelhead

New River (53.0%, *n* = 35,828), followed by the North Fork of the Trinity River (42.6%), South Fork of the Trinity River (3.8%), and Canyon Creek (0.7%) had the greatest relative abundance of summer steelhead, respectively; however, although all tributaries, except Canyon Creek, were positively correlated with the year surveyed; only the New River and South Fork Trinity River exhibited a significant increase in numbers over time. Importantly, Canyon Creek was the only tributary whose summer steelhead population, and likely its spring Chinook population, showed a relatively strong negative trend in numbers of fish over time, and had the least observed average number of fish between 1990 and 2014.

Spring Chinook

The South Fork Trinity River had, and continues to have, the greatest abundance of spring Chinook (72.8%, *n* = 9,133) in the Trinity River Basin, and their numbers appear to be unrelated to survey year. The second greatest abundance of spring Chinook was found in the New River (23.4%), which has increased significantly in numbers between 1990 and 2014. Numbers of spring Chinook in the North Fork Trinity River (1.7%) and Canyon Creek (2.1%) are relatively minor in comparison to the other two tributaries. As such, the South Fork Trinity River and New River continue to contribute significantly to spring Chinook abundances in the Trinity River tributaries.

Concordance in Annual Patters of Abundance

Fluctuations in annual patterns of abundance were largely not significant between: (1) species, (2) within adults of each taxon, or (3) among tributaries, which attests further to the variation and uniqueness of the environmental conditions associated with these unique tributaries.

RECOMMENDATIONS

Annual surveys to assess trends in summer steelhead and spring Chinook are invaluable in assessing the current status of salmonids in the Trinity River tributaries, and should continue for longevity, particularly in light of the climate change, recent severe drought, and overall environmental degradation of the watersheds, primary tributaries, and headwaters of tributaries in the Trinity Basin [(11, 12)]. Importantly, we want to emphasize that analysis of survey information for anadromous fish in Trinity River tributaries based on snorkel surveys continues to be plagued by small sample size for individual tributaries or zero data for a particular year, because of hydrological and/or logistical constraints, as well as lack of additional scheduling of surveys and staffing for this important program.

Additionally, to address some of the potential issues associated with declines in numbers of anadromous fish in the Trinity River Tributaries, additional quantitative information on hydrology, temperature, and ecological degradation of the associated tributaries and watersheds should be gathered and assessed in combination with data on population estimates derived from annual snorkel surveys, in an attempt to establish a more integrated multi-disciplinary study design and coordinated program effort.

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Appendix A. Original numerical data and notations for annual snorkel survey results from 1900 to 2014, including total numbers of fish observed on an annual basis, as well as between each species, and sampled tributary; ns = no samples taken.

	Canyon Creek			North Fork Trinity River			South Fork Trinity River			New River		
Year	Steelhead	Chinook	Grilse	Steelhead	Chinook	Grilse	Steelhead	Chinook	Grilse	Steelhead	Chinook	Grilse
2014	ns	ns	ns	751	0	0	31	83	8	500	105	27
2013	0	1	0	916	0	1	72	295	36	1233	166	56
2012	2	2	0	1161	3	0	204	773	61	1191	353	69
2011	18	10	4	953	20	4	186	242	195	1056	330	191
2010	7	7	1	794	8	1	88	105	15	853	165	48
2009	3	0	0	817	7	0	61	107	9	1036	39	47
2008	0	0	0	ns	ns	ns	ns	ns	ns	194	23	5
2007	2	0	0	392	0	0	99	202	4	853	54	4
2006	5	1	1	415	0	0	81	130	7	857	69	41
2005	7	0	0	435	1	0	39	56	11	790	3	2
2004	5	3	1	440	0	0	29	38	14	1103	9	4
2003	14	24	1	928	2	0	29	183	7	1968	57	0
2002	5	14	0	884	0	0	21	291	37	1321	2	10
2001	12	1	0	911	0	0	68	131	22	834	5	2
2000	7	3	0	327	0	0	49	204	23	460	13	0
1999	6	6	1	160	8	0	20	122	16	538**	32**	
1998	11	5	1	137	7	0	33	159	1	419	20*	
1997	18	6	0	317	3	0	76	630*		605	40*	
1996	3	7	0	347	21	0	11	1,049*		251	45*	
1995	17	35	29	829	35	15	30	447	103	765	21*	
1994	45	5	0	990	1	0	22	217	18	404	16*	
1993	24	0	2	598	14	1	23	284*		427	31*	
1992	6	0	0	367	0	0	21	136	30	272	3	15
1991	3	3	0	827	0	0	9	66*		702	2*	
1990	15	13	2	554	6	0	66	82*		343	13*	

* indicates no distinction was made between adult and grilse Chinook.

** indicates an estimate with no distinction made between adult and grilse Chinook.

Appendix B. Data used in the analyses of total numbers of fish observed on an annual basis, as well as between each species, and sampled tributary. These data include numbers of grilse in spring Chinook counts.

	Canyon Creek		North Fork Trinity River		South Fork Trinity River		New River	
Year	Steelhead	Chinook	Steelhead	Chinook	Steelhead	Chinook	Steelhead	Chinook
1990	15	15	554	6	66	82	343	13
1991	3	3	827	0	9	66	702	2
1992	6	0	367	0	21	166	272	18
1993	24	2	598	15	23	284	427	31
1994	45	5	990	1	22	235	404	16
1995	17	64	829	50	30	550	765	21
1996	3	7	347	21	11	1,049	251	45
1997	18	6	317	3	76	630	605	40
1998	11	6	137	7	33	160	419	20
1999	6	7	160	8	20	138	538	32
2000	7	3	327	0	49	227	460	13
2001	12	1	911	0	68	153	834	7
2002	5	14	884	0	21	328	1321	12
2003	14	25	928	2	29	190	1968	57
2004	5	4	440	0	29	52	1103	13
2005	7	0	435	1	39	67	790	5
2006	5	2	415	0	81	137	857	110
2007	2	0	392	0	99	206	853	58
2008	0	0	ns	0	ns	0	194	28
2009	3	0	817	7	61	116	1036	86
2010	7	8	794	9	88	120	853	213
2011	18	14	953	24	186	437	1056	521
2012	2	2	1161	3	204	834	1191	422
2013	0	1	916	1	72	331	1233	222
2014	ns	0	751	0	31	91	500	132
Totals	**235**	**189**	**15,250**	**158**	**1,368**	**6,649**	**18,975**	**2,137**

Appendix C. Grilse numerical data for annual snorkel surveys from 1900 to 2014, including total numbers of fish observed, and sampled tributary.

Year	Canyon Creek	North Fork Trinity River	South Fork Trinity River	New River	Total Grilse
	Grilse	Grilse	Grilse	Grilse	
1990	2	0			2
1991	0	0			0
1992	0	0	30	15	45
1993	2	1			3
1994	0	0	18		18
1995	29	15	103		147
1996	0	0			0
1997	0	0			0
1998	1	0	1		2
1999	1	0	16		17
2000	0	0	23	0	23
2001	0	0	22	2	24
2002	0	0	37	10	47
2003	1	0	7	0	8
2004	1	0	14	4	19
2005	0	0	11	2	13
2006	1	0	7	41	49
2007	0	0	4	4	8
2008	0	ns	ns	5	5
2009	0	0	9	47	56
2010	1	1	15	48	65
2011	4	4	195	191	394
2012	0	0	61	69	130
2013	0	1	36	56	93
2014	ns	0	8	27	35
Total	**43**	**22**	**617**	**521**	**1,203**

Appendix D. Basic statistics for total numbers of summer steelhead and spring Chinook observed on an annual basis, as well as between each species, and sampled tributary. These data incorporate numbers of grilse into numbers of spring Chinook.

	Canyon Creek		North Fork Trinity River		South Fork Trinity River		New River		Total	
Statistic	**Steelhead**	**Chinook**	**Steelhead**	**Chinook**	**Steelhead**	**Chinook**	**Steelhead**	**Chinook**	**Steelhead**	**Chinook**
N of Cases	24	25	24	25	24	25	25	25	25	25
Minimum	0	0	137	0	9	0	194	2	194	28
Maximum	45	64	1,161	50	204	1,049	1,968	521	2,939	1,261
Range	45	64	1,024	50	195	1,049	1,774	519	2,745	1,233
Sum	235	189	15,250	158	1,368	6,649	18,975	2,137	35,828	9,133
Arithmetic Mean	9.79	7.56	635.41	6.32	57.00	265.96	759.00	85.48	1,433.12	365.32
Percent	0.7%	2.1%	42.6%	1.7%	3.8%	72.8%	53.0%	23.4%	100.0%	100.0%
Skewness (G1)	2.15	3.54	-0.08	2.83	1.88	1.81	0.99	2.41	0.33	1.57
Kurtosis (G2)	6.13	14.40	-1.25	9.23	3.62	3.08	1.51	5.55	-0.26	1.69
Shapiro-Wilk Statistic	0.790	0.564	0.933	0.618	0.778	0.794	0.931	0.636	0.982	0.792
Shapiro-Wilk *p*-Value	0.000	0.000	0.115	0.000	0.000	0.000	0.091	0.000	0.928	0.000

Appendix E. Basic statistics for only counts of grilse observed on an annual basis and the associated tributary.

Statistic	**Canyon Creek**	**North Fork**	**South Fork**	**New River**	**Total**
N of Cases	24	24	19	16	25
Minimum	0	0	1	0	0
Maximum	29	15	195	191	394
Range	29	15	194	191	394
Sum	43	22	617	521	1,203
Arithmetic Mean	1.79	0.91	32.47	32.56	48.12
Percent	3.6%	1.8%	51.3%	43.3%	100.0%
Skewness (G1)	4.69	4.38	2.86	2.62	3.42
Kurtosis (G2)	22.54	20.08	8.90	8.16	13.58
Shapiro-Wilk Statistic	0.317	0.332	0.622	0.675	0.580
Shapiro-Wilk *p*-Value	0.000	0.000	0.000	0.000	0.000

Appendix F. Relationships between total numbers of summer steelhead and spring Chinook observed on an annual basis, as well as between each species and its sampled location. Pair-wise Spearman's Rank correlation (r_s) matrix below diagonal and probabilities based on sample size above diagonal. Correlations that were significant are indicated by shading according to their level of significance. Pair-wise shading in red = $p \leq 0.05$, blue = $p \leq 0.01$, purple = $p \leq 0.001$. Non-significant cells are blank. Sample size for all pair-wise comparisons was n = 23. Outlined inset represents pair-wise comparisons of counts among species within tributaries, independent of combined (total) numbers for each taxon.

Time, Species, Location	Year	Canyon Creek		North Fork Trinity River		South Fork Trinity River		New River		Total	
		Steelhead	Chinook	Steelhead	Chinook	Steelhead	Chinook	Steelhead	Chinook	Steelhead	Chinook
Year	-----------	0.050				0.001		0.050	0.050	0.050	
Canyon Cr. Steelhead	-0.443	-----------	0.050								
Canyon Cr. Chinook	-0.235	0.451	-----------	0.050							
North Fork Steelhead	0.312	0.061	0.118	-----------				0.010		0.001	
North Fork Chinook	-0.026	0.366	0.492	0.032	-----------				0.050		0.050
South Fork Steelhead	0.674	-0.042	-0.17	0.198	0.055	-----------		0.050	0.010		
South Fork Chinook	0.065	0.108	0.229	0.198	0.356	0.133	-----------		0.050		0.001
New River Steelhead	0.787	-0.351	-0.002	0.553	-0.193	0.415	-0.003	-----------		0.001	
New River Chinook	0.628	-0.202	0.036	0.185	0.454	0.580	0.429	0.367	-----------		0.001
Total Steelhead	0.603	-0.158	0.092	0.864	-0.068	0.341	0.108	0.877	0.307	-----------	
Total Chinook	0.321	0.022	0.327	0.308	0.505	0.320	0.892	0.228	0.682	0.318	-----------

Appendix G. Steelhead numerical data for annual snorkel surveys from 1900 to 2014, including total numbers of fish observed, and its sampled tributary.

Year	Canyon Creek	North Fork Trinity River	South Fork Trinity River	New River	Total Steelhead
	Steelhead	Steelhead	Steelhead	Steelhead	
1990	15	554	66	343	978
1991	3	827	9	702	1,541
1992	6	367	21	272	666
1993	24	598	23	427	1,072
1994	45	990	22	404	1,461
1995	17	829	30	765	1,641
1996	3	347	11	251	612
1997	18	317	76	605	1,016
1998	11	137	33	419	600
1999	6	160	20	538	724
2000	7	327	49	460	843
2001	12	911	68	834	,825
2002	5	884	21	1,321	2,231
2003	14	928	29	1,968	2,939
2004	5	440	29	1,103	1,577
2005	7	435	39	790	1,271
2006	5	415	81	857	1,358
2007	2	392	99	853	1,346
2008	0	ns	ns	194	194
2009	3	817	61	1,036	1,917
2010	7	794	88	853	1,742
2011	18	953	186	1,056	2,213
2012	2	1,161	204	1,191	2,558
2013	0	916	72	1,233	2,221
2014	ns	751	31	500	1,282
Total	235	15,250	1,368	18,975	35,828

Appendix H. Chinook numerical data for annual snorkel surveys from 1900 to 2014, including total numbers of fish observed, and its sampled tributary.

Year	Canyon Creek	North Fork Trinity River	South Fork Trinity River	New River	Total Chinook
	Chinook	Chinook	Chinook	Chinook	
1990	15	6	82	13	116
1991	3	0	66	2	71
1992	0	0	166	18	184
1993	2	15	284	31	332
1994	5	1	235	16	257
1995	64	50	550	21	685
1996	7	21	1,049	45	1,122
1997	6	3	630	40	679
1998	6	7	160	20	193
1999	7	8	138	32	185
2000	3	0	227	13	243
2001	1	0	153	7	161
2002	14	0	328	12	354
2003	25	2	190	57	274
2004	4	0	52	13	69
2005	0	1	67	5	73
2006	2	0	137	110	249
2007	0	0	206	58	264
2008	0	0	0	28	28
2009	0	7	116	86	209
2010	8	9	120	213	350
2011	14	24	437	521	996
2012	2	3	834	422	1,261
2013	1	1	331	222	555
2014	0	0	91	132	223
Total	**189**	**158**	**6,649**	**2,137**	**9,133**