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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

NOAA Technical Memorandum NMFS

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National Marine Fisheries Service
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Executive Summary

In response to a petition to list under the U.S. Endangered Species Act both spring-run and fall-run Chinook salmon in the Upper Klamath and Trinity Rivers (UKTR) Chinook Salmon Evolutionarily Significant Unit (ESU) the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center convened a Biological Review Team (BRT) to evaluate new information they determined to be most relevant to the questions of ESU configuration and status. This included information provided by the Petitioners in their petition, information deemed pertinent by the BRT, and information provided to the NMFS Southwest Regional Office by other parties interested in this issue. The purpose of this Technical Memorandum is to document the BRT's review and analysis of this information and to report their findings. Most importantly, the BRT concluded that the new information supported the existing UKTR Chinook ESU configuration with spring-run and fall-run populations included in a single ESU, and that the ESU is currently at a low risk of extinction within the next 100 years.

1. Background

The National Marine Fisheries Service (NMFS) received a petition to list under the U.S. Endangered Species Act (ESA) both spring-run and fall-run Chinook salmon in the Upper Klamath and Trinity Rivers (UKTR) Chinook Salmon Evolutionarily Significant Unit (ESU) and to designate critical habitat for any listed ESU. The Petitioners[1] requested that NMFS consider one of three alternatives for the listing of Chinook salmon in the UKTR: 1) list spring-run only as a separate ESU, 2) list spring-run as a distinct population segment within the UKTR Chinook Salmon ESU, or 3) list the entire UKTR Chinook Salmon ESU including both spring-run and fall-run populations.

The NMFS Southwest Region (SWR) determined that the petition presented substantial new scientific information indicating that the petitioned actions may be warranted. The SWR then requested that the NMFS Southwest Fisheries Science Center (SWFSC) convene a Biological Review Team (BRT) to 1) evaluate the extent to which the new information supports the current UKTR Chinook Salmon ESU delineation, or the separation of spring-run and fall-run Chinook salmon into separate ESUs, and 2) assess the biological status of the supported ESU configuration using the viable salmonid population framework (McElhany et al. 2000) for the analysis. The SWFSC accepted this charge and convened a BRT to evaluate the data and information they determined to be most relevant to the questions of ESU configuration and status, which included the information provided by the Petitioners and contained in their petition, other information deemed pertinent by the BRT, and the information provided to the SWR by other parties interested in this issue.

The BRT's evaluation and conclusions on these two questions are presented in this paper. It begins with the question of ESU configuration, and following that evaluation it continues with the question regarding ESU status.

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[1] Center for Biological Diversity, Oregon Wild, Environmental Protection Information Center, and The Larch Company

2. ESU Configuration

The Petitioners submit that new information demonstrates that spring-run Chinook salmon and fall-run Chinook salmon qualify as separate ESUs based on significant and persistent genetic and reproductive isolation (Petitioners 2011). Specifically, they contend that spring-run and fall-run populations in the UKTR ESU are separated by run-timing and genetic differences that are comparable to differences between spring-run and fall-run Chinook salmon in the Central Valley of California, which are recognized as separate ESUs (Petitioners 2011).

The 1998 BRT (Myers et al. 1998) acknowledged that incomplete data were available at the time to fully examine the genetic relationship between spring-run and fall-run Chinook salmon in the UKTR Chinook Salmon ESU, and their analysis was necessarily limited to a genetic comparison of hatchery stocks that may have introgressed over time as a result of hatchery spawning operations. Myers et al. (1998) recommended that their determination that spring-run and fall-run Chinook salmon populations in the UKTR ESU constitute a single ESU should be revisited if substantial new genetic information from natural spring-run populations were to become available. As the Petitioners bring forward, there is now new information on the UKTR genetic population structure of hatchery stocks, fall-run populations spawning in natural areas, and spring-run populations spawning in natural areas. In addition, the genetic analysis in Myers et al. (1998) was based on allozyme data, while new information and analyses are based on microsatellite loci. Microsatellite loci are short repeated sequences of deoxyribonucleic acid (DNA) that are typically more variable than allozymes and thus have more power to detect genetic differences.

Two key points were made by the Petitioners: 1) there is significant and persistent genetic differentiation and reproductive isolation between the UKTR spring-run and fall-run populations, and 2) the differences support separate ESUs for the UKTR spring-run and fall-run populations. The Petitioners also stated that differences in life history and genetic composition the UKTR spring-run and fall-run Chinook salmon are comparable in magnitude to the differences observed between spring-run and fall-run Chinook salmon populations in California's Central Valley, which are recognized as separate ESUs.

For spring-run and fall-run populations of Chinook salmon to be considered separate ESUs, as defined by Waples (1991) and later elaborated on by Waples (1995), these populations would need to be substantially reproductively isolated from other conspecific population units and they would need to represent an important component in the evolutionary legacy of the species. The concept of evolutionary legacy implies that there would need to be a monophyletic pattern of the evolutionary history of the two run-types within the UKTR. That is, spring-run Chinook salmon individuals and populations in the UKTR basin would need to be more similar to each other than to fall-run Chinook salmon individuals and populations within the UKTR basin (Waples et al. 2004) (Figure 1).

Populations of spring-run Chinook salmon and fall-run Chinook salmon in the same basin have been designated as separate ESUs in the California Central Valley and in the interior Columbia River Basin. In the Central Valley of California, there are four distinct phenotypic groups of Chinook salmon, distinguished primarily by run timing (winter-run, spring run, fall-run, and late fall-run), and three ESUs have been delineated (Sacramento River Winter-Run, Central Valley Spring-Run, Central Valley Fall- and Late Fall-run). These runs differ not only in run timing, but in habitat use, degree of reproductive maturity upon freshwater entry, and other phenotypic characteristics (e.g., age structure, size of smolts, etc.). Chinook salmon in the California Central Valley are monophyletic; they are all more closely related to each other than to Chinook salmon populations in any other basin. There is also significant genetic divergence among some of these Central Valley Chinook salmon runs. The Sacramento River Winter-run Chinook Salmon ESU is significantly differentiated from all other Chinook salmon runs in the Sacramento River (Myers et al. 1998; Banks et al. 2000a; Garza et al. 2007). In addition, most of the naturally spawning populations of fall-run and spring-run Chinook salmon that occur in the same tributary river of the California Central Valley are also genetically differentiated from each other, and both runs are monophyletic (Garza et al. 2007), not polyphyletic, and therefore not the result of multiple episodes of parallel evolution of the spring-run and fall-run life-history types (Lindley et al. 2004). The exception to this pattern is in the Feather and Yuba rivers, where spring-run and fall-run populations are closely related and genetically most similar to Central Valley fall-run Chinook salmon, but this is the result of historical and ongoing hybridization of spring-run and fall-run salmon at the Feather River Hatchery (Garza et al. 2007). In contrast, the fall-run and the late fall-run are genetically very similar and cannot be reliably distinguished from each other with genetic identification methods, which is one of the reasons that they were not separated into two ESUs (Myers et al. 1998; Garza et al. 2007). Myers et al. (1998) and all subsequent analyses and reviews concluded that the genetic population structure of the Chinook salmon in the California Central Valley supports separate ESUs for spring-run and fall-run populations (Lindley et al. 2004, Waples et al. 2004).

In the interior Columbia Basin, spring-run and fall-run Chinook salmon are not closely related and represent two divergent evolutionary lineages (Myers et al. 1998; Waples et al. 2004). Several fall-run and spring-run Chinook salmon ESUs have been delineated by Myers et al. (1998) in the mid- and interior-Columbia River and Snake River basins, and both the spring-run and fall-run populations are monophyletic. This pattern is not consistent with a scenario involving parallel evolution of one of the life-history types in multiple sub-basins. Also of note is that spring-run Chinook salmon populations in the mid- and interior Columbia River basin exhibit a yearling outmigrant life history, which includes at least a full year of stream residence before smolting (Healey 1991), whereas the fall-run populations are predominantly sub-yearling outmigrants (Myers et al. 1998).

In all other coastal drainages and the lower Columbia River Basin fall-run and spring-run Chinook salmon are not delineated into separate ESUs, although differences in adult run-timing, life-history strategies, and other phenotypic characteristics are sometimes accompanied by genetic differences. The genetic population structure observed in these basins strongly suggests a polyphyletic pattern of run timing evolution (Myers et al. 1998; Waples et al. 2004). Such polyphyletic evolution of spring-run and fall-run populations is observed in basins adjacent to the Klamath Basin and across a range of watershed sizes including the Mad River, Redwood Creek, and Eel River in the California Coastal Chinook Salmon ESU and the Rogue River and Umpqua River in the Southern Oregon and Northern California Coast Chinook Salmon ESU.

In a review of life-history evolution in Chinook salmon, Waples et al. (2004) considered juvenile and adult life-history traits from more than 100 populations in California, Oregon, Washington, Idaho, and British Columbia, in the context of evolutionary relationships inferred from molecular genetic data taken from these same populations. Waples et al. (2004) found that run-timing diversity has developed independently by a process of parallel evolution multiple times in the species. However, within coastal basins (including the Klamath and lower Columbia basins), genetic differences among populations with different run-timing were modest and generally considered as reflecting patterns of within-ESU diversity as concluded by Myers et al. (1998). Waples et al. (2004) also found that different run-timing and other correlated life-history traits of Chinook salmon in the interior Columbia River Basin were clearly associated with two long-divergent genetic run-type lineages, consistent with their delineation into two ESUs by Myers et al. (1998).

The new data cited by the Petitioners, specifically from the study by Kinziger et al. (2008a), as well as additional data from Kinziger et al. (2008b; In Preparation) provided the BRT with genetic data and analyses of sufficient resolution to consider whether spring-run and fall-run Chinook salmon populations in the UKTR ESU meet the biological criteria for separate ESUs. One other genetic study focusing specifically on Chinook salmon in the Klamath Basin (Banks et al. 2000a) has become available since Myers et al. (1998). In addition, work by Waples et al. (2004), Lindley et al. (2004), and Garza et al. (2007) provided the BRT with a more fully-informed context by which to evaluate patterns of genetic population structure and population differentiation in the spring-run and fall-run UKTR Chinook salmon populations compared to those observed in populations of Chinook salmon in other basins. Given the new genetic information and analyses for hatchery and natural spawning populations in the UKTR ESU, and the additional published work available for context, the BRT approach was to review these reports and publications to determine 1) if the sampling and methods were appropriate, 2) if the conclusions were supported by the analyses and results, and 3) if this new information provided support for the delineation of a single UKTR ESU, as delineated by Myers et al. (1998), or if these new findings support separate fall-run UKTR and spring-run UKTR ESUs.

The existence of extant populations of spring-run and fall-run Chinook salmon in the UKTR ESU was acknowledged by Myers et al. (1998) and was not an issue of contention raised by the Petitioners. The BRT therefore focused its attention on the new genetic data and information specifically brought forward by the Petitioners, as well additional data that were directly relevant to the issue of whether Chinook salmon in the UKTR with different run timing should be one or two ESUs. Recent data by Hearsey (2011) supports the conclusion that there are two run types of Chinook salmon in the Klamath Basin and that there are reported differences between the two run-types besides time of freshwater entry. Hearsey (2011) reported that spring-run adult fish enter freshwater up to four months prior to spawning, had greater fat reserves, arrived less mature, and appeared to be of smaller size at maturity.

In general, spring-run Chinook salmon found in the UKTR ESU exhibit a predominantly sub-yearling smolt migration (so-called “ocean type”), migrating within one year of hatching, similar to that observed in fall-run Chinook salmon in the Klamath River (Myers et al. 1998). The Petitioners cite Healy (1991) as the source for classifying spring-run Chinook salmon in the UKTR ESU as having a “stream-type” juvenile life history, meaning smolt migration following more than one year of freshwater residence. Classification of all spring-run Chinook salmon populations throughout the species range as “stream-type” is often attributed to Healey (1991). However, Healey (1991) did not specifically review spring-run Chinook salmon in the Klamath Basin and does acknowledge that there are some apparent exceptions in Oregon streams where spring-run adults produce sub-yearling smolts. Originally, the “ocean-type” and “stream-type” designation were used to describe two divergent genetic lineages in the interior Columbia

River, where there is a strikingly different pattern from that observed in all other basins (Waples et al. 2004). Myers et al. (1998) found that all populations of Chinook salmon south of the Columbia River drainage appear to consist predominantly of sub-yearling migrants. Snyder (1931) found that six of the 35 (17.1%) Klamath River spring-run adult Chinook salmon that he observed in 1920 had emigrated as yearlings, this was similar to the 13% yearling outmigrant rate observed among fall-run Chinook salmon (1919-1923) which are uniformly classified as "ocean-type". The BRT also reviewed other information on life-history characteristics compiled by Myers et al. (1998) and concluded that none of this information supported a "stream-type" designation for spring-run Chinook salmon (as defined by Healey [1991]) in the UKTR ESU, nor did any of the new life history information presented by the Petitioners to support the "stream-type" designation.

In Kinziger et al. (2008a), 12 Chinook salmon populations from the Klamath and Trinity basins were examined using 17 microsatellite loci. Included in the sample were collections from all drainages supporting appreciable numbers of spawners, including natural and hatchery populations, and spring- and fall-run populations (Kinziger et al. 2008a). In addition, they reviewed hatchery records dating from 1943 to 1994 pertaining to hatchery-spawned Chinook salmon in California. The major findings of Kinziger et al. (2008a) relevant to this petition include the finding that the extant populations sampled exhibited a substantial degree of genetic structure despite the large amount of out-of-basin stock importation that historically occurred in the Klamath and Trinity basins. They found four genetically differentiated and geographically separated groups of Chinook salmon in the Klamath-Trinity Basin (Upper basin[2], Trinity [including spring- and fall-run from the Trinity River Hatchery and the South Fork Trinity River], Salmon [containing spring- and fall-run from the Salmon River], and Lower Basin[2]), and their data indicated that spring- and fall-run Chinook salmon life-histories have repeatedly evolved in parallel within both the Salmon and Trinity rivers in an independent fashion.

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[2] Kinziger et al. (2008) used the term Upper Basin to represent populations from Iron Gate Hatchery, Shasta River, and Scott River and the term Lower Basin to represent populations from Horse Linto Creek (a tributary of the lower Trinity River), Blue Creek, and Terwer Creek (all located near or downstream of the confluence of the Trinity and Klamath rivers).

In a more recent study Kinziger et al. (In Preparation) examined 790 individuals from 10 naturally-spawning and three hatchery populations using 27 microsatellite loci. All of the same populations examined by Kinziger et al. (2008a) were included in this analysis along with samples from Bogus Creek, located near Iron Gate Hatchery at the current upstream limit of migration in the Klamath River. In this study, with the additional sampling and increased number of loci (27 versus 17), Kinziger et al. (In Preparation) found a strong pattern of genetic isolation-by-distance, with genetic distance between populations strongly predicted by geographic distance, independent of run-timing (Figure 2). They also found the same lineages as Kinziger et al. (2008a), including the lower basin, upper Klamath River, and the Trinity River, and found that the Salmon River populations were intermediate between (i.e., experienced gene flow) the upper Klamath River and Trinity River groups (Figures 3 and 4). More significant to the petition, Kinziger et al. (In Preparation) found that spring-run and fall-run populations from the Salmon River exhibited non-significant levels of genetic differentiation between them (Figure 5) and were nearly indistinguishable genetically. They also confirmed the earlier results of Kinziger et al. (2008a, 2008b) that Trinity River Hatchery spring-run and fall-run salmon are extremely closely related and that two run types (fall-run and spring-run) were more genetically similar to one another than they were to any other populations in the basin (Figures 3 and 5; Kinziger et al. In Preparation). Kinziger et al. (In Preparation) also examined fall-run and spring-run Chinook salmon in the South Fork Trinity River and found that they were extremely similar to both each other and to the Trinity River Hatchery stocks, but the ability to detect differentiation was limited by small sample sizes.

The Petitioners stated that genetic differentiation is scaled similarly in both the Central Valley ESUs and the UKTR ESU and, therefore, that the designation of Central Valley spring-run and fall-run populations as separate ESUs sets a precedent for the UKTR ESU to also be separated into a fall-run ESU and a spring-run ESU. The Petitioners cite Banks and Barton (1999), which is an interim report on the project fully described in Banks et al. (2000a) as providing new information for dividing the UKTR ESU into two ESUs based on run-timing. The BRT concluded that these new data and information and the conclusions of Banks et al. (2000a) and Kinziger et al. (2008a, 2008b, In Preparation) support the current single ESU configuration. Banks et al. (2000a) reported that they observed greater genetic distance among some of the fall-run populations than among fall-run and spring-run populations in the Klamath Basin (Figure 6). In addition, Banks et al. (2000a) found that the pattern seen in the Klamath River differed from that in the Central Valley:

> *"As found in Banks and Bartron (1999), geographic origin of samples appears more important than life history. As might be expected typically, populations appear to have diverged according to geographic location first and life history second. This finding is in strong contrast to those made from a study of California's Central Valley sub-populations."*

Moreover, Banks et al. (2000a) found that populations from the Central Valley clustered primarily according to life-history type (fall-run, spring-run) resulting "in a tree that had little in common with the geographic origin of samples despite the greater distance between samples from the Central Valley in comparison to distances between samples of the Klamath and Trinity basin."

The configuration of Central Valley spring-run and fall-run Chinook salmon populations was recently reviewed by Lindley et al. (2004), Good et al. (2005), and Garza et al. (2007). All supported the general conclusions that Central Valley Chinook salmon of all run-types represent a separate lineage from all other Chinook salmon populations coastwide (as discussed by Waples et al. 2004), and that Central Valley spring-run populations are monophyletic, with the exception of the hatchery-dominated stock from the Feather and Yuba rivers, with spring-run from different basins more closely related to each other than to fall-run Chinook salmon from the same sub-basin. Lindley et al. (2004), Good et al. (2005), and Garza et al. (2007) support the conclusion of Banks et al. (2000a, 2000b) that the genetic population structure and genetic variation observed in Chinook salmon populations in the Central Valley of California is structured by life-history (run-type) rather than geographic location, unlike what is observed in the extant UKTR Chinook salmon populations.

The observation of genetic differentiation among populations also separated by life-history traits does not necessarily imply that they represent different ESUs. The new data and information (Banks et al. 2000a, Kinziger et al. 2008a; Kinziger et al. 200b; Kinziger et al. In Preparation) indicate that population differentiation does exist among populations in the UKTR Chinook Salmon ESU. Evolutionarily significant units are delineated and defined by deep evolutionary divergence and represent major independent lineages within a species, within which variation and structure change on time scales of tens to hundreds of generations. Salmon populations are arranged hierarchically, from individuals, to populations, to ESUs, up to the entire species, so within an ESU, one expects to see population structure and differentiation. It is the clustering of population groups (and life-history groups), their spatial arrangement on the landscape, and the extent of their genetic and life-history divergence from one another along this hierarchy that would determine whether to delineate population units into separate ESUs. The BRT concluded that the differences and patterns of differentiation observed among populations of Chinook salmon in the UKTR ESU were insufficient to warrant consideration as separate ESUs.

In summary, recent studies provide genetic population structure analyses based on samples of spring-run and fall-run Chinook salmon from natural and hatchery populations in the Klamath River Basin. Myers et al. (1998) recommended that the current UKTR ESU configuration which includes both spring-run and fall-run populations be revisited if substantial new genetic information from natural spring-run populations were to become available. The BRT thus considered these new data and analyses from Kinziger et al. (2008a) and Kinziger et al. (In Preparation), along with other new information (e.g., Banks et al. 2000a; Lindley et al. 2004; Waples et al. 2004; Good et al. 2005; Garza et al. 2007; Kinziger et al. 2008b) in their evaluation of whether this new information supports the current delineation of a single ESU (Myers et al. 1998) or whether it supports a delineation of two separate ESUs (spring-run and fall-run) as proffered by the Petitioners. The BRT concluded that the new information supports the ESU delineation of Myers et al. (1998) in which UKTR spring-run and fall-run Chinook salmon populations constitute a single ESU, and that the expression of the spring-run life-history variant is polyphyletic in origin in all of the populations for which data are available.

The BRT reached this conclusion using a “likelihood point” method. This approach, often referred to as the FEMAT method, was used by the BRT when voting on ESU structure and later for judging risk facing an ESU. This approach, described in Good et al. (2005), has been used in all status review updates for anadromous Pacific salmonids since 1999 and allows for BRT members to express any uncertainty they may have concerning ESU structure and actual risk facing an ESU. The majority (86%) of the BRT votes were to retain the UKTR Chinook salmon designation that includes both spring-run and fall-run Chinook salmon as a single ESU (Table 1).

3. Biological Status of Upper Klamath and Trinity River Chinook Salmon ESU

The BRT used a similar approach to that of Good et al. (2005) to assess the status of the UKTR Chinook Salmon ESU in the absence of viability criteria developed by a Technical Recovery Team (TRT). Such viability criteria have not been developed for this ESU because it has not previously been considered at risk of becoming endangered or at risk of extinction. Since the UKTR ESU has no historical population structure delineated by a TRT, and therefore VSP populations (i.e., demographically independent populations, DIPs) have therefore not been identified, the BRT used the putative population components that are currently recognized by management agencies in the Klamath Basin. These population components typically represent sub-basin units (e.g., Scott River) or specific geographic areas (e.g., upper Klamath mainstem). Spring-run and fall-run populations within a population component are separately assessed.

Current Distribution

There have been no changes to the distribution of UKTR Chinook salmon since the review of Myers et al. (1998). The upstream boundaries of anadromy continue to be Iron Gate Dam on the Klamath River and Lewiston Dam on the Trinity River. In addition, Dwinnell Dam on the Shasta River is a migration barrier. Adult Chinook salmon are distributed throughout the Basin below these migration barriers.

Historical Abundance

Myers et al. (1998) summarized the available information concerning historical abundances of Chinook salmon in the UKTR ESU and reported an estimated peak run-size of 130,000 Chinook salmon in 1912 (based on peak cannery pack of 18,000 cases). Given that by 1912 much of the habitat in the UKTR had been impacted by mining and other land-use activities, this peak run estimate is likely an underestimate. In addition, California Department of Fish and Game (CDFG 1965) estimated the spawning escapement of fall-run and spring-run fish Chinook salmon "as they existed at about 1963" to be approximately 168,000 adults, with the number split about evenly between the Klamath (88,000) and Trinity (80,000) rivers.

Recent Abundance, Trends in Abundance, and Population Growth Rate

Current estimates of spawning escapement and run-size continue to be monitored by a combination of state, federal, and tribal agencies. Two hatcheries exist within the UKTR Chinook Salmon ESU, Iron Gate Hatchery (Rkm 310 on the mainstem Klamath River at the base of Iron Gate Dam, the current limit of upstream access) and Trinity River Hatchery (Rkm 182) on the mainstem Trinity River and located near Lewiston Dam, the current limit of upstream migration on the mainstem Trinity River). California Department of Fish and Game enumerates the escapement to these two hatcheries. Spawning escapement to the Upper Klamath, Trinity, Scott, Salmon, and Shasta rivers, as well as smaller tributaries, is cooperatively estimated by a consortium of tribes, agencies, and non-governmental organizations using a variety of methods including carcass surveys, weir counts, redd surveys, and mark-recapture studies (Myers et al. 1998; KRTT

2011). Resting pool counts of adult spring-run Chinook salmon in the Salmon River, upper Trinity River, and South Fork Trinity River are derived from snorkel surveys.

Spawner escapement estimates are available from both hatcheries and from nine component populations (Figures 7 and 8 and Table 2). These estimates were obtained from the California Department of Fish and Game (CDFG 2011a; CDFG 2011b), the Pacific Fishery Management Council (Pacific Fishery Management Council 2011, Appendix B), and the U.S. Forest Service (USFS 2011). It was not possible to separate hatchery and natural-origin fish from the data for these component populations, and therefore escapement estimates used to assess status were not segregated by origin. Using these total adult (age > 2) spawner escapement estimates, we characterized the recent abundance, trend in spawning escapement, and population growth rate using methods described below.

Recent abundance of population components was assessed by computing the geometric mean and range of adult spawner escapement for the most recent five years (Table 2), consistent with previous coast-wide status reviews (Good et al. 2005). If data were missing within the most recent five years, the geometric mean and range were computed using only the available data within that five-year period, and missing data are noted in Table 2.

Trends in spawning escapements were estimated by fitting a linear regression model to the time series of natural logarithm transformed adult spawner data

$$\ln(N_t) = \beta_0 + \beta_1 t + \varepsilon , \qquad (1)$$

where N_t is adult spawner escapement in year t, β_0 is the intercept, β_1 is the slope, and ε is a normally distributed error term with mean zero and variance σ^2. Trend is expressed as $\exp(\hat{\beta}_1)$ with 95% confidence intervals $\exp(\hat{\beta}_1 \pm t_{0.025,df} \times se)$, where $t_{0.025,df}$ is the critical value of the Student's t distribution at probability 0.025 and degrees of freedom df, and se is the standard error of $\hat{\beta}_1$. Trend values less than one indicate declining spawning escapements, while trend values of one or greater indicate stable or increasing spawning escapements. Long-term trend was estimated using all available data for the population component. Short-term trend was estimated from data spanning the most recent 13 years (generally 1998–2011). Missing data for population components is noted in Table 2. The model represented by Equation (1) is a model of geometric growth (or decline) fitted to adult spawner escapement data. Such data for salmon populations are characterized by high levels of process noise and sampling error, and this complicates status assessments based on models fitted to annual escapement data (McClure et al. 2003). In addition, a given year's escapement does not fully reflect the overall population abundance at that time (immature fish will spawn in later years). Some of these problems are alleviated by focusing evaluation on the *population growth rate*. For this reason, the BRT focused primarily on estimates of the population growth rate to determine whether a population was in decline.

The population growth rate (λ) and 95% confidence intervals were estimated (Table 2) using methods described in Dennis et al. (1991), which are briefly summarized here. To partially reduce the influence of process and measurement error, four-year running sums of adult spawner escapement estimates, $R_t = \sum_{i=0}^{3} N_{t-i}$, were computed (McClure et al. 2003, Good et al. 2005). Estimation of λ required estimates of the mean ($\hat{\mu}$) and variance ($\hat{\sigma}^2$) of the natural logarithms of successive ratios of R:

$$\hat{\mu} = mean\left\{\ln\left(\frac{R_{t+1}}{R_t}\right)\right\} \qquad (2)$$

$$\hat{\sigma}^2 = \operatorname{var}\left\{\ln\left(\frac{R_{t+1}}{R_t}\right)\right\}. \qquad (3)$$

From these

$$\hat{\lambda} = \exp\left(\hat{\mu} + \frac{\sigma^2}{2}\right) \qquad (4)$$

where the addition of $\hat{\sigma}^2/2$ yields a (nearly) unbiased estimator of λ (Dennis et al. 1991). 95% confidence intervals for λ are given by Equation 68 in Dennis et al. (1991). Values of λ less than one suggest a population in decline, while values greater than one indicate an increasing population. Long-term estimates of λ were made from all data available for a population component when there were no missing data. The use of the four-year running sum of escapement makes missing data problematic. Therefore, in cases where there are missing data for a population component, the longest uninterrupted series of data are used; these instances are noted in Table 2. Short-term estimates of λ were made from the 13 most recent years of adult spawner escapement data (generally 1998-2010), which results in ten four-year running sums (9 ratios). Instances of missing data are handled in the same way as for the long-term trend and are noted in Table 2. While we present both short-term and long-term population growth rate, to be consistent with Good et al. (2005), we viewed population growth rates based on just 13 years of data with caution given the highly variable population dynamics typical of salmon populations and influences of shifting environmental conditions. Of most interest to the BRT were the long-term population growth rates of the populations individually and the ESU as a whole[3].

Recent escapement estimates of both fall-run and spring-run fish returning to spawn in natural areas in the UKTR Chinook Salmon ESU are generally low compared to estimates of historical abundance, although all but one of the populations (Upper Trinity spring-run) have a long-term λ of 1.0 or greater, indicating that the populations have not been in decline since the late 1970s and early 1980s (or earlier, in the case of the Shasta

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[3] A major motivation of BRTs presenting long- and short-term population growth rate estimates is to distinguish between populations that were once very large and suffered historical declines but have stabilized at lower abundances from populations with ongoing declines. This was a particular issue for populations with very long time series of abundance (e.g., certain Columbia River Chinook salmon populations). Such very long time series aren't available for the Klamath basin, so presentation of long- and short-term trends is arguably less important.

River; Table 2). The Upper Trinity spring-run spawner abundance estimates were highly variable from 1980 to 2010 (Figure 8), and missing data in 1995 limited the data used for calculating the long-term λ to the period between 1996 and 2010 (Table 2). The rather large 95% confidence interval for the long-term λ for this population results from this variability and the few continuous data available. In addition, the data range for the long-term λ estimate has been truncated to nearly the same length as that used for the short-term estimate, resulting in the long- and short-term λ being quite similar. The short-term λ values for four of the nine populations were less than 1. However, as previously mentioned, the BRT considered these short-term estimates of λ with caution. Spawner returns to Iron Gate and Trinity River hatcheries are illustrated in Figures 7 and 8. Spawner returns of fall-run and spring-run to Trinity River Hatchery have been more variable than spawner returns of fall-run Chinook salmon to Iron Gate Hatchery. Spawner returns to the two hatcheries did not mirror spawner returns of similar run-type fish in the adjacent natural populations, with the exception of Bogus Creek and the mainstem Klamath River (Figure 7), which are adjacent to Iron Gate Hatchery. In addition, the short-term trend for Bogus Creek was the lowest estimated trend in spawning escapement (0.900) for the fall-run populations examined by the BRT. Also of note is the similar trend in adult spawner returns of Salmon River spring-run and fall-run Chinook salmon (Figure 9).

The BRT concluded that there has been little change in the abundance levels, trends in abundance, or population growth rates since Myers et al. (1998). The BRT noted however, as did Myers et al. (1998), that the recent abundance levels of some populations are low, especially in the context of historical abundance estimates. In particular, the recent spawner abundance levels of two of the three spring-run population components (Salmon River and South Fork Trinity River) are below 1,000 fish (Table 2).

Hatchery-origin Spawners in Natural Areas

The occurrence of hatchery-origin spawners in natural areas since (approximately) the year 2000 is summarized below by region. The uncertainty of estimates of the hatchery-origin fish in natural areas is large, specifically for hatchery fish from the Iron Gate

Hatchery that until recently had not been tagged/marked (i.e., adipose fin clipped) or were marked at very low rates. Besides sporadic estimates based on expansion of marked fish observed on the spawning grounds, genetic data provided the BRT with information about past contributions of hatchery-origin fish to local populations. The genetic population structure data indicate that the greatest similarity among populations in natural areas and hatchery stocks occurs in those areas adjacent to the hatcheries (Bogus Creek near-adjacent to Iron Gate Hatchery and South Fork Trinity River spring- and fall-run fish populations near Trinity River Hatchery). Expansion estimates based on low marking rates and few recoveries might lead to estimates of rather large numbers of hatchery-origin fish in natural areas (e.g., 30%) that are not supported by the genetic population structure data.

Bogus Creek – The percent of fall-run Chinook salmon that were hatchery-origin was estimated to range from 7.5% to 61.6% between 1999 and 2011, although the hatchery contribution was likely underestimated between 1999 and 2002 owing to the lack of tagging/marking of yearling production at Iron Gate Hatchery for brood years 1997 and 1998 (Knechtle and Chesney 2011a; M. Knechtle, California Department of Fish and Game, Yreka, California, personal communication).

Upper Klamath River – The number of adipose-fin-clipped fall-run Chinook salmon carcasses handled during spawning surveys has been very low (<2%). Expansion of the adipose-clipped fish capture rates by the mark-rate yields an estimated hatchery fish contribution ranging from 0.8% to 31.6% for the years 2001 to 2008. The uncertainty of these estimates is high (Gough and Williamson 2009).

Shasta River – The percent of fall-run Chinook salmon spawners the Shasta River that were of hatchery origin was estimated to range from 0.9% to 38.7% (mean = 10.6%) between 2002 and 2010 (Chesney and Knechtle 2011; M. Knechtle, California Department of Fish and Game, Yreka, California, personal communication).

Scott River – The presence of adipose-clipped fish in this basin is very rare and contributions are not estimated (Knechtle and Chesney 2011b; M. Knechtle, California Department of Fish and Game, Yreka, California, personal communication).

Salmon River – The presence of adipose-clipped fish in this basin is very rare and and contributions are not estimated (W. Sinnen, California Department of Fish and Game, North Coast Region, personal communication).

Trinity River – The distribution of Chinook salmon spawning in the Trinity River tends to be concentrated near the dam (limit to upstream migration), with the highest concentration of hatchery-origin fish spawning near the dam whereas natural-origin fish spawn at the greatest frequency near the dam but are also found in areas tens of kilometers downstream of the dam where few hatchery-origin fish are observed spawning (C. Chamberlin, U.S. Fish and Wildlife Service, Arcata, California, personal communication). Carcass surveys in the Trinity River indicated that hatchery-origin fish contribution to spring-run spawning in the mainstem Trinity River ranged from 8.4% to 38.0% from 2002 to 2009, with the value trending lower in the most recent years.

South Fork Trinity River – There is little ability to observe adipose-clipped fish in the surveys, though hatchery contribution is thought to be low (W. Sinnen, California Department of Fish and Game, North Coast Region, personal communication).

Based on genetic population structure data and the available spawner survey data, the BRT concluded that the majority of hatchery-origin Chinook salmon straying to natural areas for spawning occurs in the areas adjacent to the two hatcheries. This is not an unexpected finding given that both hatcheries release their production "on-site", as opposed to at other locations further downstream in the basin. The finding is substantiated by the genetic analysis results reviewed earlier in this report (Kinziger et al., In Preparation) that found strong evidence for genetic isolation-by-distance in UKTR Chinook salmon (Figure 2). Such a pattern would not exist if hatchery-origin fish were straying in large numbers throughout the basin.

Fishery Exploitation Rates

Information on fishery exploitation rates were available for fall-run Chinook salmon and not for spring-run Chinook salmon in the Klamath River. However, an in-river tribal exploitation rate was developed for this review, and some inferences about the effect of ocean fisheries on spring-run Chinook salmon were made.

The spawner reduction rate for fall-run Chinook salmon in the Klamath River was similar to that noted in the previous review by Myers et al. (1998). This rate represents the fraction of potential natural-area adult spawners reduced by harvest and harvest-related actions (e.g., release mortality) in ocean and river fisheries. The reduction rate was variable and in general ranged from 0.24 to 0.67 during the period from 1996 to 2010 (Figure 10). Rates of ocean harvest of age-4 Klamath River fall-run Chinook salmon have generally remained similar or lower since the previous review (Myers et al. 1998), except for a relatively high rate observed in 2004 (Figure 11). The in-river tribal exploitation rates (computed as tribal catch divided by the sum of tribal catch and spawner escapement) have been similar to, or have slightly increased from level estimated in the previous review (Myers et al. 1998), particularly for spring-run fish (Figure 12). In-river recreational fishery exploitation rates are not known for spring-run fish in the Klamath or Trinity rivers.

For spring-run Chinook salmon, ocean exploitation-rate information is not available, although one could assume equality in rates between Klamath fall-run and spring-run Chinook salmon. Such an assumption may be problematic. If maturation rates between fall-run and spring-run fish are equal (which is unsubstantiated) and ocean distribution is identical, the exploitation rate on spring-run would be lower than the exploitation rate on fall-run, since spring-run return to the river in the spring, making them largely invulnerable to summer ocean fisheries in the last year of life. It should also be noted that under the weak-stock management approach to ocean salmon fisheries, limits to fishing imposed by the status of other stocks (such as Sacramento River fall-run Chinook) likely afford protection to Klamath River spring-run Chinook salmon as well.

In summary, the overall fishery exploitation rate on fall-run Chinook salmon in the Klamath Basin has remained relatively unchanged since the previous review (Myers et al. 1998).

Factors Considered in Risk Assessment

As discussed by Good et al. (2005), previous West Coast salmon and steelhead BRTs used a “risk matrix” to quantify ESU-scale risks according to major risk factors. Good et al. (2005) provide a revised matrix (Table 3) for the risk assessment process that directly addresses the four primary viable salmon population (VSP) criteria described by McElhany et al. (2000): abundance, productivity, spatial structure, and diversity in the risk assessment process. We used this revised matrix for our risk assessment process for UKTR Chinook salmon. Following our review and discussion of all relevant biological information for the ESU, each BRT member assigned a risk score to each of the four VSP criteria using a 5-point scale, ranging from very low risk to high risk (Good et al. 2005, page 15). Although the risk matrix is a valuable tool for directly focusing our evaluation and assessment of ESU risks in terms of VSP criteria, it does not provide a convenient means of assessing overall risk to the ESU.

As indicated by the risk matrix scores (Table 4), the BRT had the greatest concern about diversity (2.9), followed by a similar level of concern for abundance (1.9), growth/productivity (1.9), and spatial structure/connectivity (2.0). A summary of the BRT’s general comments and considerations underlying these risk matrix scores follows.

Abundance: In general, spawner abundance and variability in spawner abundance of the UKTR population components appear to have been fairly stable for the past 30 years and since the previous review (Myers et al. 1998). Abundance is generally low compared with historical abundances, but does not constitute a major risk in terms of extinction. Long-term population growth rates for all but one component are greater than 1.0, indicating that they are not in decline. In general, most populations are large enough to avoid genetic problems.

Growth rate/productivity: There was no indication that growth rates and productivity have changed since the last review (Myers et al. 1998), although the impact of hatchery-origin fish in several locations and in some years was uncertain and a concern to the BRT. Hatchery influence appeared to be most concentrated in the areas adjacent to the two hatcheries, and spawning survey information (adipose fin-clipped fish) and genetic analyses indicate low hatchery influence in areas not adjacent to the hatcheries.

Spatial structure and connectivity: There is a broad geographic distribution of fall-run Chinook salmon in the UKTR ESU, with isolation-by-distance indicating that there was connectivity among populations throughout the ESU. As in the previous review (Myers et al. 1998), concern remains about how much production from the two hatcheries may drive population dynamics in nearby natural areas. There were no examples of unused available habitat (i.e., extirpations), and the spatial distribution of fall-run Chinook salmon in the UKTR ESU appears appropriate for the current state of the habitat. Spring-run population numbers are low, with few if any fish recently observed in the Scott and Shasta rivers. The distribution of spring-run is of some concern, with possible extirpations perhaps reflecting the effects of low water years and habitat accessibility.

Diversity: Although there are extant spring-run and fall-run populations in the UKTR Chinook Salmon ESU, the low spawner abundance of fish in the extant spring-run populations was a concern for the BRT, as it was with the previous review (Myers et al. 1998). It is unknown how diversity has changed from historical conditions; some BRT members expressed concern that overall genetic diversity may be fairly low. Besides the expression of spring-run and fall-run life-history types, the presence of large sub-yearlings in the Shasta River was encouraging. As noted previously, the BRT was concerned about the amount of straying of hatchery-origin fish in the basin, most notably in the areas adjacent to the two hatcheries and its possible impacts on the productivity of natural populations.

Recent events: The BRT also considered known recent events and their possible impacts (positive and/or negative) on extinction risk. Trinity River restoration activities were mentioned by several BRT members, although long-term evaluations are needed. Recent land acquisitions in the Shasta River watershed by conservation organizations were mentioned by several BRT members as likely to reduce extinction risk. Increased knowledge of disease infection rates in the Klamath River was considered to be favorable. Recent work by Fujiwara et al. (2011) concluded that ceratomyxosis affects the population dynamics of fall-run Chinook salmon populations, with the effects being localized in the Klamath River in areas upstream of an infection zone (mainstem Klamath River from the confluence of Seiad Creek upstream to the confluence of Shasta River); therefore impacting spawning abundance trends in areas upstream of the zone that include Bogus Creek and the Shasta River. Changes in flow prescriptions in the Klamath Basin were considered positive (i.e., reduced extinction risk), although water quality issues were a concern. Water temperatures in the Klamath River mainstem and its tributaries were a concern, as they perhaps create impacts on connectivity.

Summary of Risk Evaluation

The BRT used the FEMAT method to conduct the overall extinction risk assessment for the UKTR Chinook Salmon ESU. The assessment reflected the informed professional judgment by each BRT member, based on both the quantitative and qualitative information reviewed in this report and the results of the risk matrix analysis. Each BRT member allocated 10 points (votes) among three possible extinction risk categories so as to reflect their own uncertainty in making this judgment. The three possible extinction risk categories used were: “high risk”, “moderate risk”, and “neither at high risk or moderate risk” (low risk). Quantitative and qualitative conservation assessments for other species have often used a 100-year time frame in their extinction risk evaluations (Morris et al. 1999, McElhany et al. 2000) and the BRT adopted this time scale as the period over which it evaluated risk. With guidance from the NMFS Southwest Regional Office, the BRT interpreted the high risk category as “a greater than 5% risk of extinction within 100 years” and the moderate risk category as “a more likely than not risk of moving into the high risk category within 30 – 80 years”. Beyond these time horizons, the projected effects on UKTR Chinook salmon viability from climate change, ocean conditions, and trends in freshwater habitat become very difficult to predict with any degree of confidence.

A majority (63%) of the BRT votes were in the low-risk category, with minorities falling in the moderate-risk (36%) and high-risk (1%) category (Table 5). Only one out of 90 votes was placed in the high-risk category.

Significant Portion of the Range

As part of this review, the BRT considered the issue of whether the UKTR Chinook Salmon ESU was at risk of extinction throughout a significant portion of its range (SPOIR). The BRT was asked by the Southwest Regional Office of NMFS to consider the issue of SPOIR to help inform their deliberations on this petition. The phrase "significant portion of its range" in the Endangered Species Act's definitions of "endangered and "threatened species" provides an independent basis for listing. Thus there are two situations under which a species would qualify for listing: a species may be endangered or threatened throughout all of its range, or a species may be endangered or threatened in only a significant portion of its range.

The definition of "significant" used by the BRT was provided by the NMFS Southwest Regional Office: a portion of the range of a species is significant if its contribution to the viability of the species is so important that, without it, the species would be in danger of extinction. The geographical range of the listing unit considered for this process was the current distribution of UKTR Chinook Salmon ESU. The lost portion of the historical range (e.g., upstream of dams) was relevant to the analysis of ESU status, but, according to SWR guidance, it cannot constitute a significant portion of an ESU's range. The BRT assumed that SPOIR could refer to a geographic sub-unit of the current ESU (e.g., the Salmon River), or to a life-history variant (i.e., spring-run or fall-run life-history type).

The BRT found that there was broad geographic representation for Chinook salmon in the UKTR ESU, with genetic isolation-by-distance among the component populations indicating connectivity among the populations throughout the ESU. There were no examples of unused habitat (i.e., extirpations), and the spatial distribution of Chinook salmon in the ESU appears appropriate for the current state of the habitat.

Although the BRT was concerned about the relatively few populations of spring-run Chinook salmon and the low numbers of individual fish in those populations (discussed earlier), it did not conclude that these spring-run populations were at immediate risk of extinction and did not find that their demographic status poses an immediate risk of extinction to the ESU. Although the complete loss of spring-run would reduce the viability of the ESU, the BRT concluded that the complete loss of spring-run would not result in an immediate risk of extinction to the UKTR Chinook Salmon ESU.

Climate Change

Recently climate change effects in the Klamath Basin were reviewed by Woodson et al. (2011), where the results from three global climate models[4] and a vegetation model were used to project future temperature, precipitation, vegetation, runoff, and wildfire in the Klamath Basin. Some general conclusions from the review by Woodson et al. (2011) on climate change projections for the Klamath Basin include 1) all three models pointed to a warmer future for the Klamath Basin with greater relative warming in the summer than in other seasons, 2) all three models projected drier summers, however projections for winter precipitation varied considerably among the three models, 3) annual stream runoff projections varied considerably among the models with two of the three projecting lower annual stream flows and the third projecting higher flows, and 4) there have been changes in predominant vegetation types. Vegetation changes included a decline in the maritime conifer forest in the lower basin, and projections are for the upper basin to change from sagebrush and juniper to conditions that favor grasslands. As a result, wildfires are projected to increase from 11% to 22%, with greater area burned late in the century compared to the historical average.

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[4] The three models used included: The Commonwealth Scientific and Industrial Research Organization (CSIRO) model, the Hadley Centre Coupled Model (HADCM) model, and the Model for Interdisciplinary Research on Climate (MIROC) model.

The projections of climate change discussed by Woodson et al. (2011) would clearly have impacts on fish communities in the Klamath Basin, including UKTR Chinook salmon. Some of the effects discussed by Woodson et al. (2011) include that the shorter wet season projected by most of the models will likely alter fish migration and timing and possibly decrease the availability of side channel and floodplain habitats. Groundwater-fed springs will decrease and may not flow year around; Woodson et al. (2011) project that this could be particularly critical in the Shasta River and other areas along the Klamath River and could result in the loss of cool-water refuge areas. Woodson et al. (2011) also discuss possible impacts on disease incidence resulting from increased water temperature, and they consider water temperature impacts on dissolved oxygen levels and potentially earlier, longer, and more intense algae blooms. Quiñones (2011) reviewed climate change issues and impacts on salmon and trout in the Klamath River and concluded that climate change will likely exacerbate existing stressors as well as create new stressors.

4. Conclusions

The BRT evaluated data and information determined to be relevant to the questions of ESU configuration and status of the UKTR Chinook Salmon ESU, which included information provided by the Petitioners and contained in their petition, other information deemed pertinent by the BRT, and information provided to the SWR by other parties interested in this issue. As to the extent to which the new information supports the current UKTR Chinook Salmon ESU configuration or the separation of spring-run and fall-run Chinook salmon into separate ESUs, the BRT found that the new information supports the current UKTR Chinook ESU configuration with spring-run and fall-run populations included in a single ESU as proposed by Myers et al. (1998). As to the status of the UKTR Chinook Salmon ESU, the BRT found that the ESU is currently at low risk of extinction within the next 100 years.

The BRT had three areas of particular concern related to extinction risk to the UKTR Chinook Salmon ESU. First, the BRT was concerned about the relatively few populations of spring-run Chinook salmon and the low numbers of spawners within those populations. Multiple life-history types provide diversity to the ESU, both within and among populations, and while the BRT did not conclude that these low numbers posed an immediate risk of extinction to the ESU, there was concern that appropriate habitat and conditions that allow for the expression of the spring-run life history were limited. The decline in spring-run fish was especially troubling given that historically the spring-run fish may have been equally numerous, if not more numerous, than the fall-run (Barnhart 1995). Second, the contribution of hatchery-origin fish spawning in natural areas was high adjacent to the two hatcheries, and there were indications that some hatchery-origin fish were spawning in areas not adjacent to the hatcheries. The potential impact of this introgression of hatchery-origin spawners on the productivity of natural populations, particularly in those areas adjacent to the two hatcheries, was a concern to the BRT. Third, although the possible changes in the physical environment that climate change may bring to the Klamath Basin and the attendant consequences on fish populations are uncertain, it is possible that these changes will exert significant pressure on Chinook salmon populations in the UKTR unless mitigated by restoration of habitat and access to higher-elevation areas.

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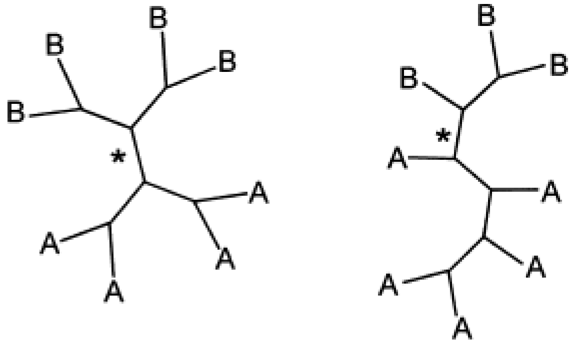
Woodson, D., K. Dello, L. Flint, R. Hamilton, R. Neilson, and J. Winton. 2011. Climate change effects in the Klamath Basin. Pages 123 to 149 *in* L. Thorsteinson, S. VanderKooi, and W. Duffy, editors. Proceedings of the Klamath Basin Science Conference, Medford, Oregon, 1 – 5 February 2010. U.S. Geological Survey Open-File Report 2011-1196. Available on-line at: http://pubs.usgs.gov/of/2011/1196/pdf/ofr20111196.pdf

Single evolutionary event



Parallel evolution

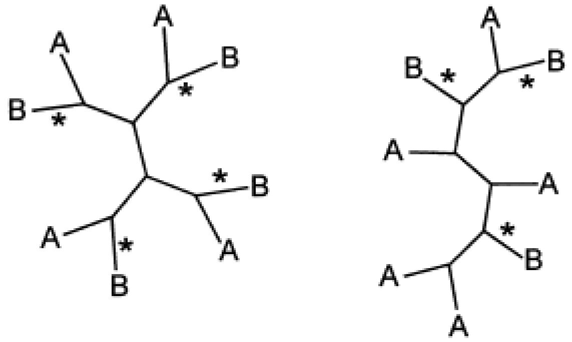


Figure 1. Two generalized patterns of evolution of life-history traits. An asterisk denotes an evolutionary change. Top panel: The pattern of genetic/life-history relationships can be explained by a single episode in which trait B evolved from trait A (or vice versa). Bottom panel: A minimum of four (left) or three (right) parallel evolutionary changes is required to explain the observed pattern of relationships (Waples et al. 2004).

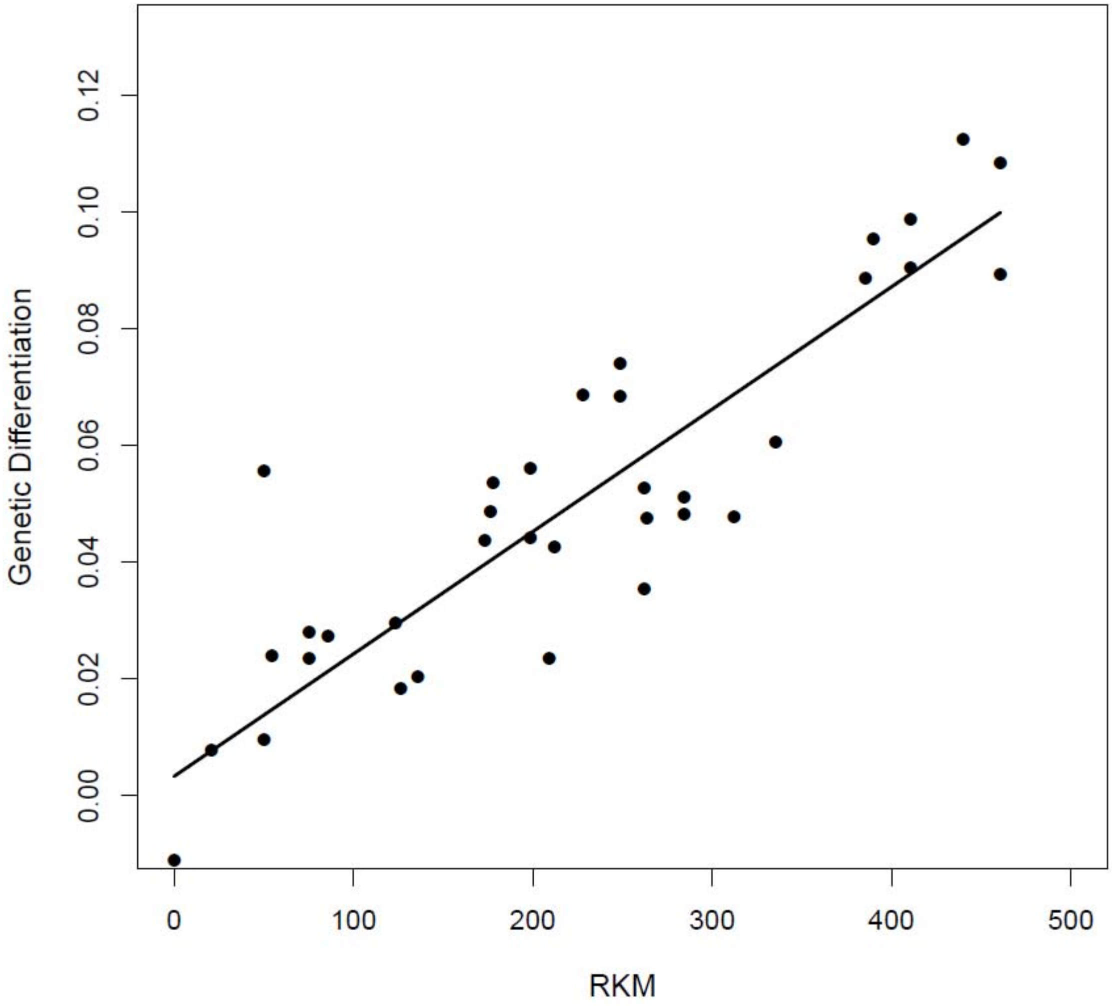


Figure 2. From Relationship between pairwise genetic differentiation (G′$_{ST}$) and river distance for Klamath River Chinook salmon above Klamath and Trinity river confluence (excludes Horse Linto Creek) (Kinziger et al. In Preparation).

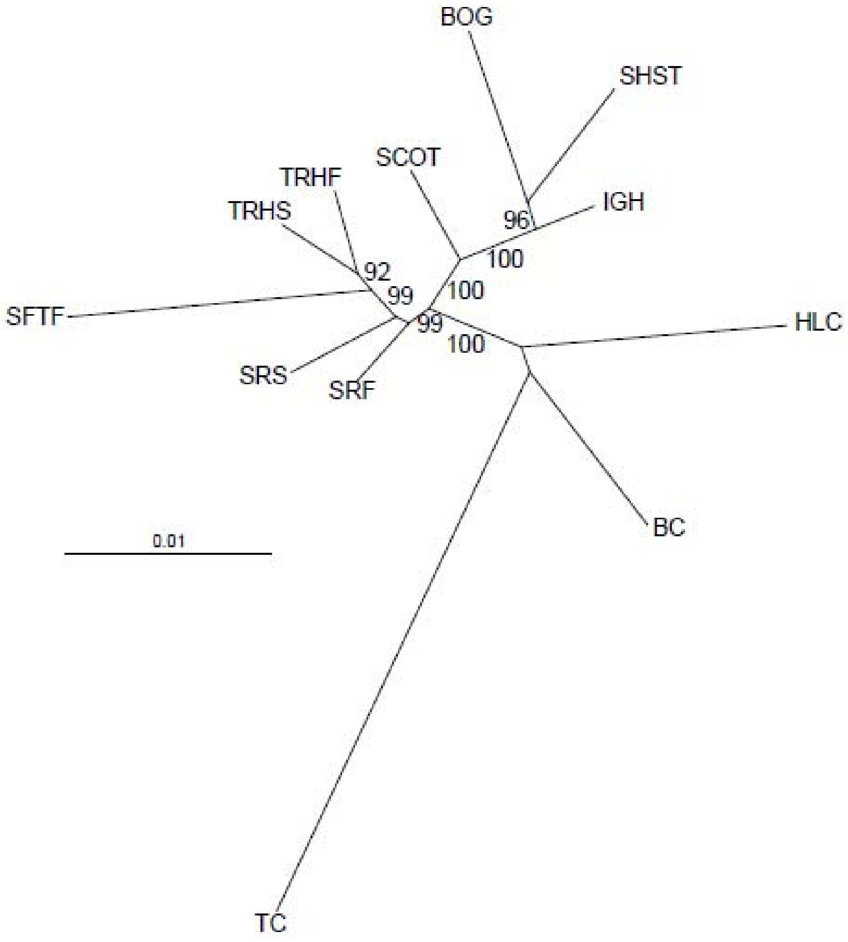


Figure 3. Genetic relationships among UKTR Chinook salmon populations are depicted in an unrooted neighbor-joining tree based on microsatellite DNA data and generated using PYYLIP. Branch lengths are equivalent to Cavalli-Sforza genetic distance. Bootstrap support labeled along branches. Codes are: IGH: Iron Gate Hatchery, BOG: Bogus Creek, SHST: Shasta River, SCOT: Scott River, SRS: spring-run Salmon River, SRF: fall-run Salmon River, TRHS: spring-run Trinity River Hatchery, TRHF: fall-run Trinity River Hatchery, SFTF:fall-run South Fork Trinity River, HLC: Horse Linto Creek, BC: Blue Creek, TC: Terwer Creek (Kinziger et al. In Preparation).

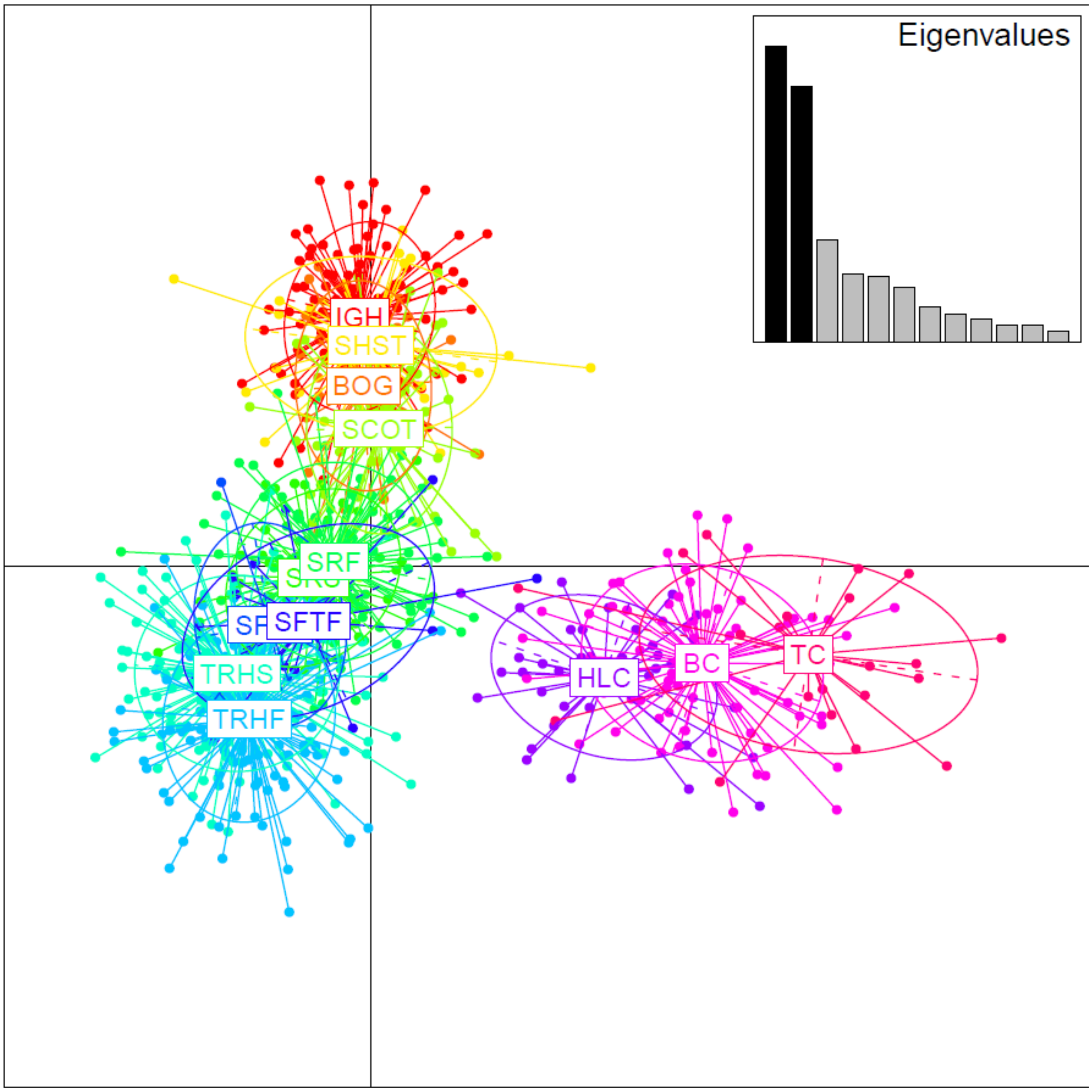


Figure 4. Visualization of genetic relationships among UKTR Chinook salmon populations from Kinziger et al. (In Preparation). Scatterplot shows the first two principal components of DAPC using population locations as prior clusters. Populations are labeled inside their 95% inertia ellipsis and dots represent individuals. The inset indicates the eigenvalues of the analysis.

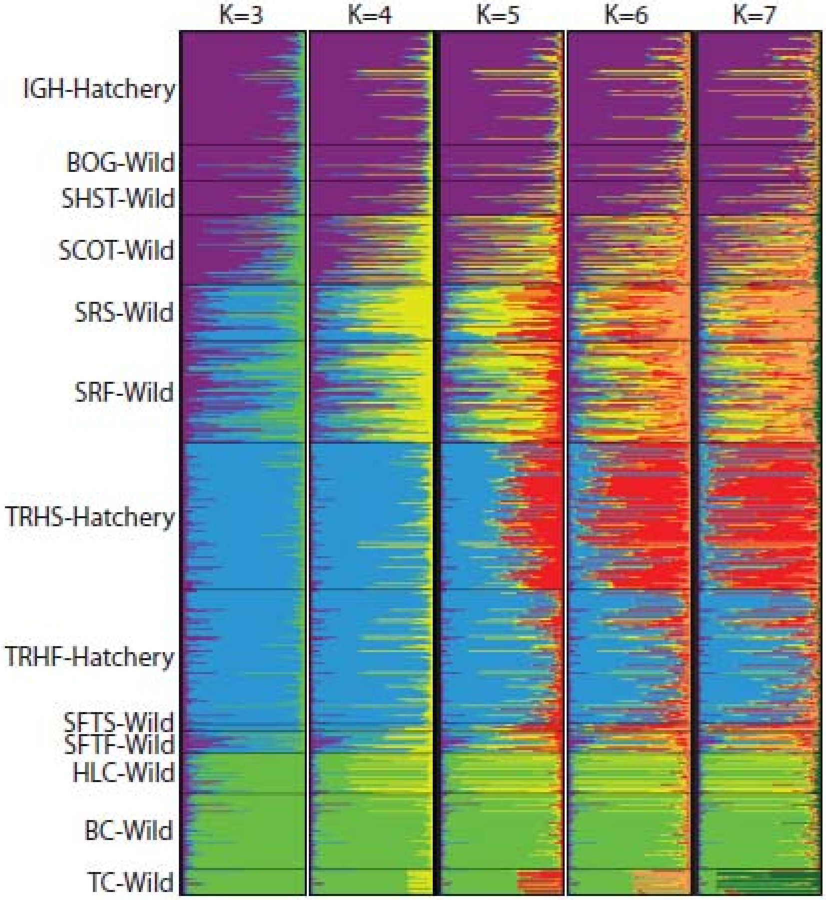


Figure 5. Depciation of UKTR Chinook salmon genetic population structure from Kinziger et al. (In Preparation). Individual membership coefficients (Q) for Klamath River Chinook salmon for 3 to 9 clusters (K) without the use of population location information (IGH-Hatchery: Iron Gate Hatchery fall-run; BOG-Wild: Bogus Creek natural origin fall-run; SHST-Wild: Shasta River natural origin fall-run; SCOT-Wild: Scott River natural origin fall-run; SRS-Wild: Salmon River natural origin spring-run; SRF-Wild: Salmon River natural origin fall-run; TRHS-Hatchery: Trinity River Hatchery spring-run; TRHF-Hatchery: Trinity River Hatchery fall-run; SFTS-Wild: South Fork Trinity River natural origin spring-run; SFTF: South Fork Trinity River natural origin fall-run; HLC-Wild: Horse Linto Creek natural origin fall-run; BC-Wild: Blue Creek natural origin fall-run; TC: Terwer Creek natural origin fall-run.

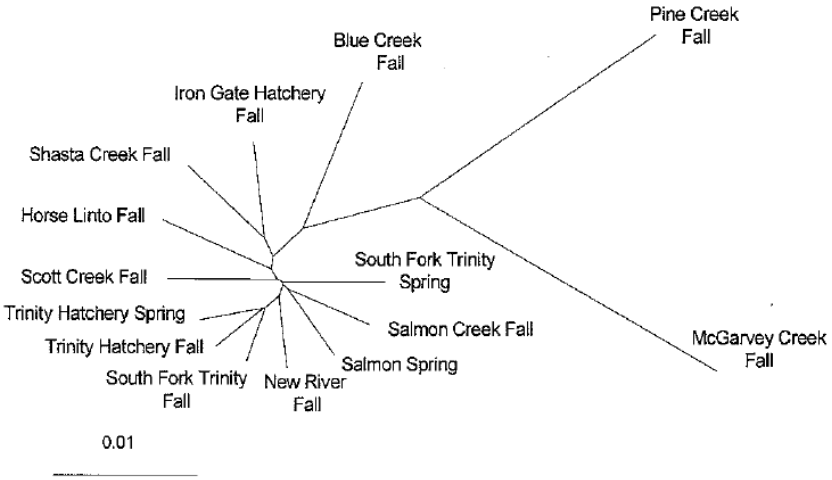


Figure 6. UPGMA phenogram of population samples from fall-run and spring-run Chinook salmon populations of the Klamath and Trinity basins based on seven microsatellite loci (Banks et al. 2000a).

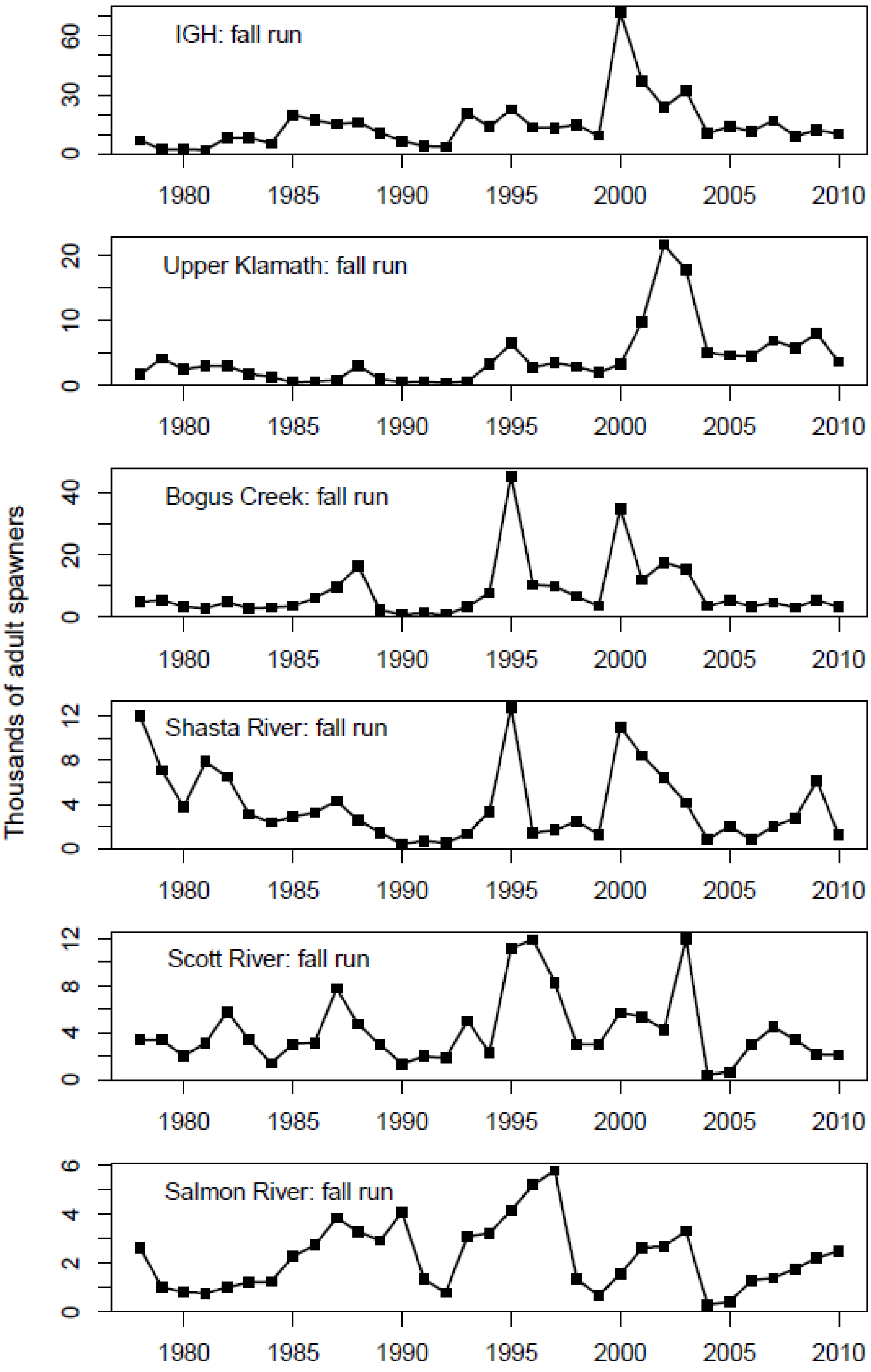


Figure 7. Time series of adult Chinook salmon escapement, Klamath River.

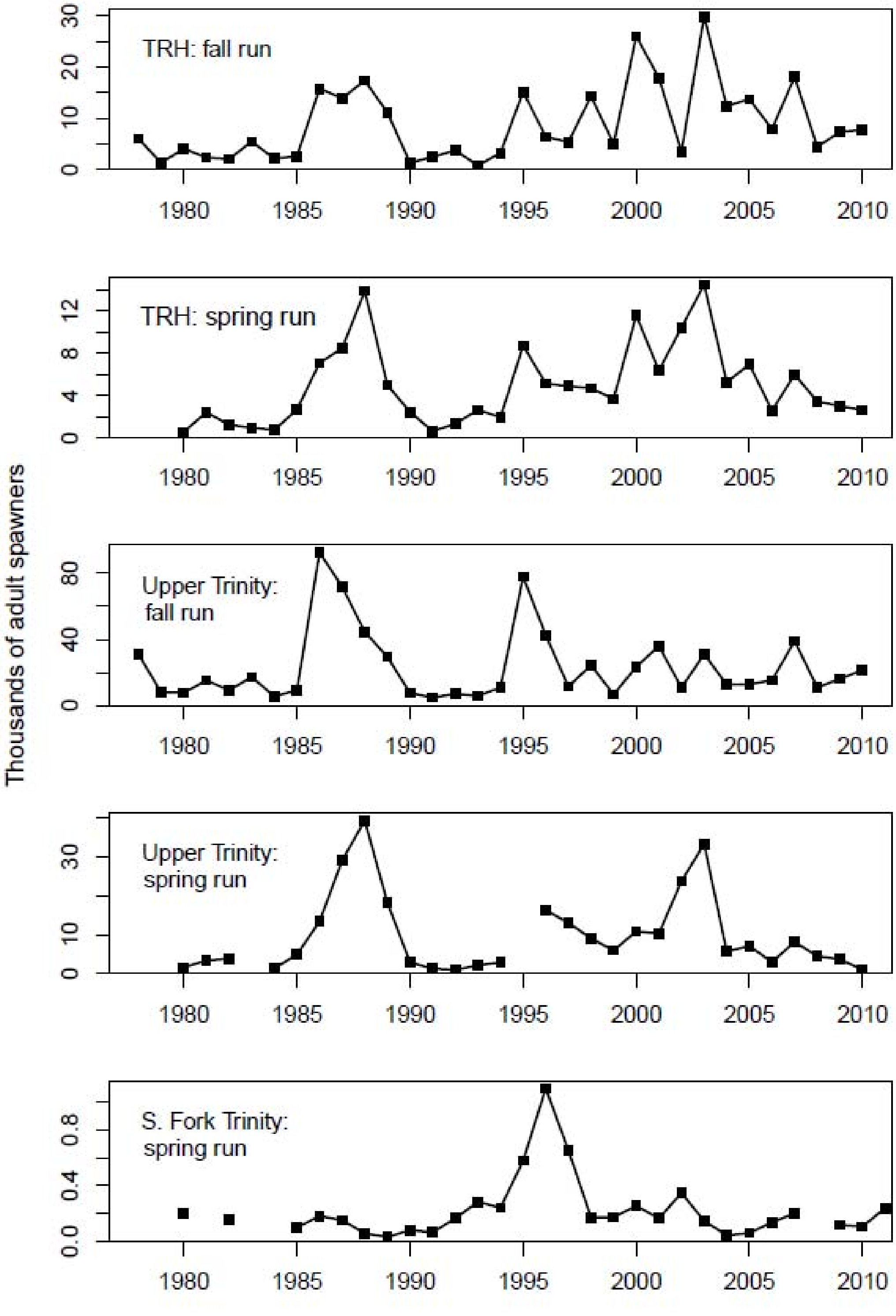


Figure 8. Time series of adult Chinook salmon escapement, Trinity River.

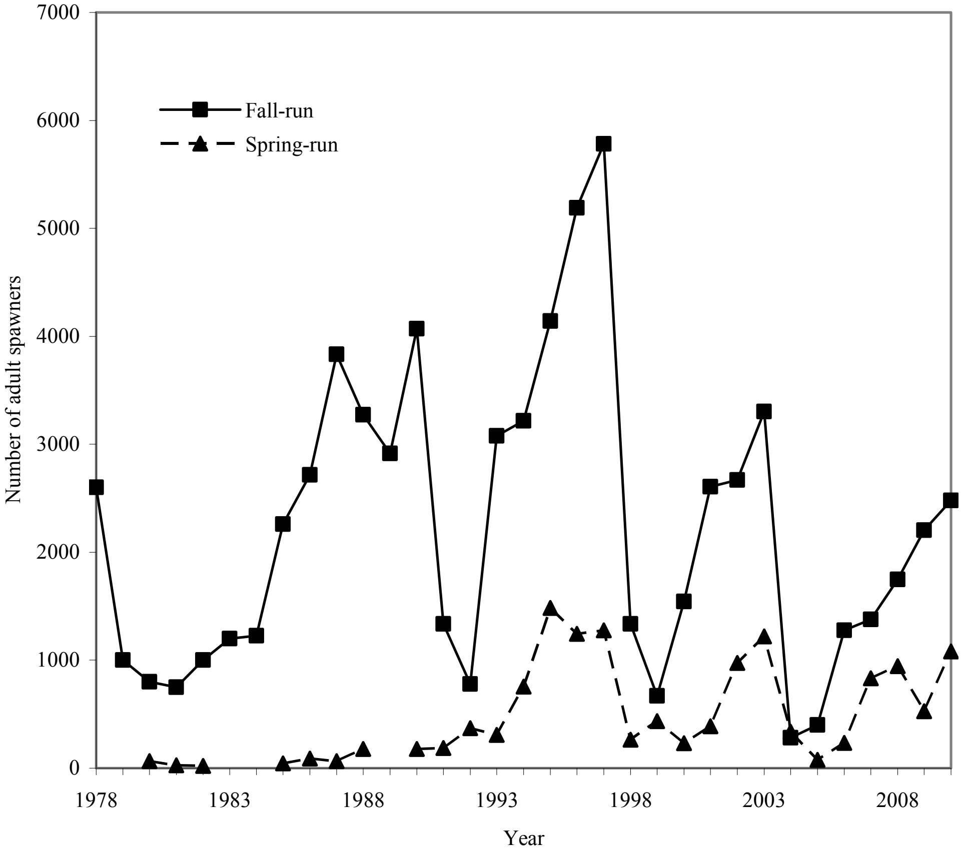


Figure 9. Time series of adult fall-run and spring-run Chinook salmon returning to the Salmon River. Spring-run adult number is resting pool count.

Figure 10. Time series of Klamath River fall Chinook salmon spawner reduction rate. These rates represent fractions of potential spawners that have been reduced by harvest and harvest-related actions.

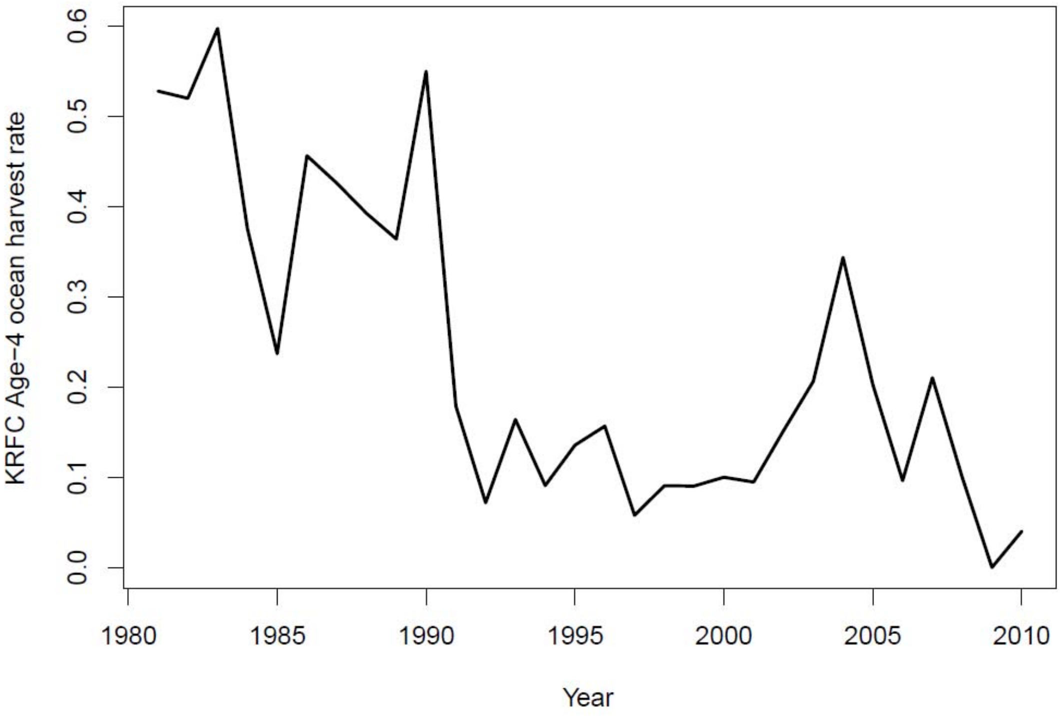


Figure 11. Time series of Klamath River fall Chinook salmon age-4 ocean harvest rate.

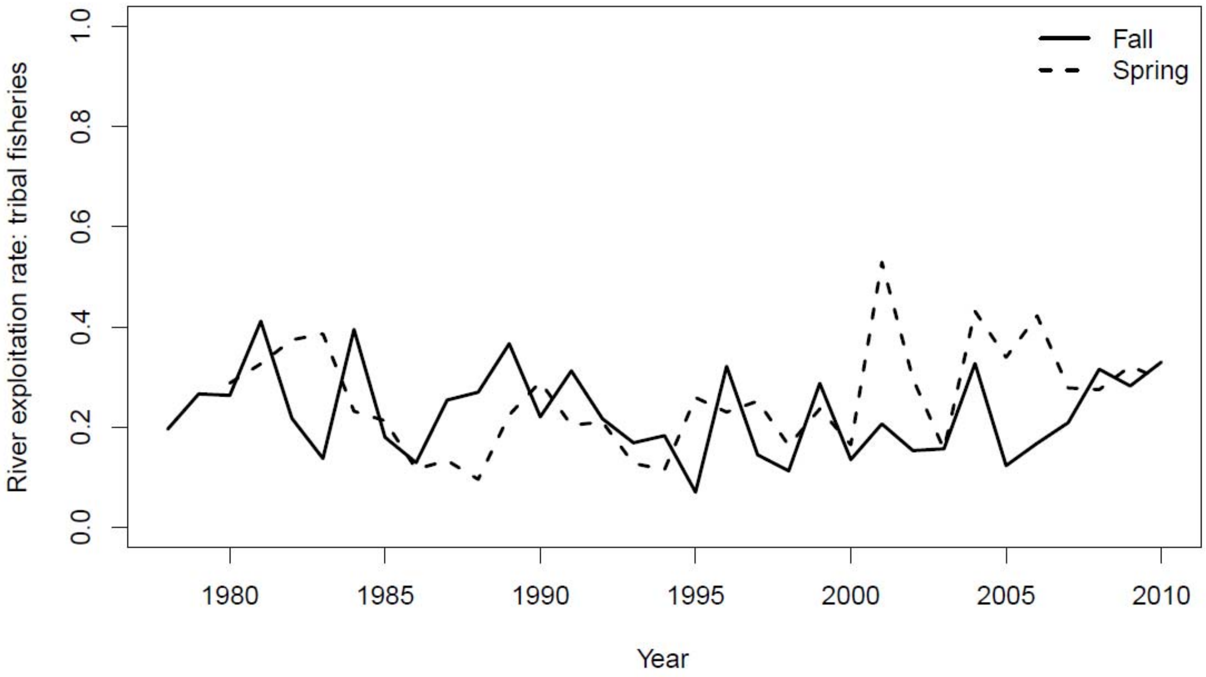


Figure 12. Time series of Chinook salmon in-river tribal fishery exploitation rate.

Table 1. Tally of the BRT FEMAT vote distribution for the ESU configuration of the Upper Klamath Trinity River Chinook Salmon ESU. Each of the ten BRT members allocated 10 points among the two configurations (single ESU, two ESUs representing an UKTR spring-run ESU and an UKTR fall-run ESU).

ESU configuration	Number of votes	Percent of total
One ESU	77	86%
Two ESUs	13	14%

Table 2. Recent spawner abundance, trends in spawner abundance, and population growth rate for population components of the Upper Klamath and Trinity River Chinook Salmon ESU. Data from Pacific Fishery Management Council (20111, Appendix B), CDFG (2011a), and CDFG (2011b); methods described by Good et al. (2005).

		Recent abundance		Long-term			Short-term		
Population component	Run	Years	Geometric mean (range)	Years	Trend (95% CI)	λ (95% CI)	Years	Trend (95% CI)	λ (95% CI)
Bogus Creek	Fall	2006-2010	3826 (3001 – 5455)	1978-2010	1.019 (0.984-1.055)	1.140 (0.935-1.391)	1998-2010	0.900 (0.803-1.008)	0.902 (0.755-1.077)
Upper Klamath	Fall	2006-2010	5568 (3684-7945)	1978-2010	1.060 (1.026-1.095)	1.101 (0.956-1.267)	1998-2010	1.029 (0.916-1.155)	1.102 (0.866-1.402)
Shasta River	Fall	2006-2010	2020 (789-6145)	1930-2010[a]	0.980 (0.969-0.992)	1.052 (0.949-1.166)	1998-2010	0.941 (0.816-1.086)	0.990 (0.781-1.255)
Scott River	Fall	2006-2010	2922 (2113-4494)	1978-2010	0.995 (0.968-1.023)	1.037 (0.939-1.146)	1998-2010	0.946 (0.821-1.092)	1.009 (0.821-1.240)
Salmon River	Fall	2006-2010	1758 (1278-2478)	1978-2010	1.000 (0.972-1.028)	1.049 (0.953-1.155)	1998-2010	1.026 (0.903-1.165)	1.076 (0.877-1.320)
Upper Trinity	Fall	2006-2010	18729 (11006-39038)	1978-2010	1.008 (0.978-1.039)	1.114 (0.942-1.316)	1998-2010	1.004 (0.918-1.097)	1.010 (0.905-1.128)
Salmon River	Spring	2006-2010	636 (233-1081)	1980-2010[b]	1.101 (1.058-1.146)	1.133 (0.962-1.335)	1998-2010	1.066 (0.937-1.214)	1.154 (0.959-1.388)
Upper Trinity	Spring	2006-2010	3288 (962-8154)	1980-2010[c]	1.010 (0.965-1.058)	0.962 (0.799-1.157)	1998-2010	0.868 (0.769-0.979)	0.976 (0.776-1.229)
S. Fork Trinity	Spring	2007-2011[d]	158 (108-240)	1980-2011[e]	1.005 (0.969-1.043)	1.056 (0.899-1.239)	1999-2011[f]	0.973 (0.879-1.078)	0.880 (0.728-1.065)

a – Year range for long-term applies only to trend, for λ the year range is 1957-2010; missing data for 1950 and 1956.
b – Year range for long-term applies only to trend, for λ the year range is 1990-2010; missing data for 1983, 1984, and 1989.
c – Year range for long-term applies only to trend, for λ the year range is 1996-2010; missing data for 1983 and 1995.
d – Missing data for 2008, data from 2009 includes jacks.
e – Year range for long-term applies only to trend, for λ the year range is 1985-2007. Data from 2009 includes jacks. Missing data for 1981, 1983, 1989, and 2008.
f – Year range for short-term applies only to trend, for λ the year range is 1999-2007. Data from 2009 includes jacks. Missing data for 2008.

Table 3. Template for the risk matrix used in BRT deliberations. The matrix is divided into five sections that correspond to the four viable salmonid population parameters from McElhany et al. (2000) plus a recent events category (Good et al. 2005).

Risk category	Score[a]
Abundance Comments:	
Growth rate/productivity Comments:	
Spatial structure and connectivity Comments:	
Diversity Comments:	
Recent events[b]	

a – Rate overall risk of ESU on 5-point scale, from 1 (very low risk) to 5 (very high risk); see Good et al. (2005, page 15) for full description.
b – Recent events range from ++ (expect a strong improvement in status of the ESU) to – (expect strong decline in status); see Good et al. (2005; page 15) for full description.

Table 4. Summary of risk scores (1 = low to 5 = high) for four VSP categories for the Upper Klamath Trinity River Chinook Salmon ESU.

VSP Criteria	Mean	Range (Min – Max)
Abundance	1.9	1 – 3
Growth rate / productivity	1.9	1 – 3
Spatial structure / connectivity	2.0	1 – 3
Diversity	2.9	2 – 4

Table 5. Tally of the FEMAT vote distribution for extinction risk of the Upper Klamath Trinity River Chinook Salmon ESU. Each of ten BRT members allocated 10 points among the three risk categories (low, moderate, high).

Risk category	Number of votes	Percent of total
Low	57	63%
Moderate	32	36%
High	1	1%

SWFSC Technical Memorandums

SWFSC Technical Memorandums are available online at the SWFSC web site (http://swfsc.noaa.gov). Copies are also available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (http://www.ntis.gov).