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To: Wr401program
Subject: Karuk Comments on dEIR for Lower Klamath Project
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Attachments: Thompson et al. 2018 PNAS.pdf
2017 Prince et al. Science Advances.pdf
18-07-23 FINAL signed CA ESA petition UKTR Spring Chinook.pdf
19-02-19 Karuk Ethnography comments for dEIR.pdf
17_11_08 DOI Ltr re HR 3535.pdf
Karuk_WQCP_Main_final 2.20.14.pdf
19-02-26 Karuk dEIR comments FINAL.pdf

Please accept the attached comment letter and associated document from Karuk Tribe as our comments on the dEIR on the Lower Klamath Project.

Regards,

C

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Anthropogenic habitat alteration leads to rapid loss of adaptive variation and restoration potential in wild salmon populations

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Phenotypic variation is critical for the long-term persistence of species and populations. Anthropogenic activities have caused substantial shifts and reductions in phenotypic variation across diverse taxa, but the underlying mechanism(s) (i.e., phenotypic plasticity and/or genetic evolution) and long-term consequences (e.g., ability to recover phenotypic variation) are unclear. Here we investigate the widespread and dramatic changes in adult migration characteristics of wild Chinook salmon caused by dam construction and other anthropogenic activities. Strikingly, we find an extremely robust association between migration phenotype (i.e., spring-run or fall-run) and a single locus, and that the rapid phenotypic shift observed after a recent dam construction is explained by dramatic allele frequency change at this locus. Furthermore, modeling demonstrates that continued selection against the spring-run phenotype could rapidly lead to complete loss of the spring-run allele, and an empirical analysis of populations that have already lost the spring-run phenotype reveals they are not acting as sustainable reservoirs of the allele. Finally, ancient DNA analysis suggests the spring-run allele was abundant in historical habitat that will soon become accessible through a large-scale restoration (i.e., dam removal) project, but our findings suggest that widespread declines and extirpation of the spring-run phenotype and allele will challenge reestablishment of the spring-run phenotype in this and future restoration projects. These results reveal the mechanisms and consequences of human-induced phenotypic change and highlight the need to conserve and restore critical adaptive variation before the potential for recovery is lost.

conservation | evolution | genetics | biodiversity | salmon

Phenotypic variation buffers species and populations against environmental variability and is important for long-term persistence (1–7). In phenotypically diverse populations, environmental fluctuations that negatively impact one phenotype may have a neutral or positive impact on another (5, 8). This decreases variance in population size across time and reduces vulnerability to extirpation or extinction. Furthermore, phenotypic variation increases the potential for species to persist through long-term environmental changes (e.g., climate change) by serving as the substrate upon which evolution can act. Thus, maintaining intraspecific phenotypic variation is an important component of biodiversity conservation.

Anthropogenic activities have major effects on phenotypic variation across a broad array of species and traits, often producing substantial phenotypic shifts and reductions in overall variation (5, 6, 9–12). Despite the recognized importance of intraspecific variation, the urgency of addressing human-driven phenotypic change through conservation policy and action is unclear because the ability of affected populations and/or species to recover previous characteristics (e.g., variation) is not well understood (5, 13, 14). If previous variation can quickly reemerge, human-induced phenotypic change may have limited impact on long-term persistence and evolutionary potential. However, permanent changes and reductions in variation could have severe consequences such as limiting potential response to future environmental fluctuations, constraining the ability to colonize new habitat that may become available and curtailing evolutionary potential (15–17). Thus, in cases where anthropogenic activities threaten the potential to recover previous characteristics, immediate steps to reduce human impacts on intraspecific phenotypic variation are warranted.

The mechanisms that underlie human-induced phenotypic change (i.e., phenotypic plasticity and/or genetic evolution) will influence the potential for previous characteristics to reemerge.

Significance

Human activities alter and reduce phenotypic variation in many species, but the long-term consequences (e.g., ability of previous variation to reemerge), and thus the need for conservation action, are unclear. Here we show that dramatic, human-induced changes in adult migration characteristics of wild Chinook salmon are explained by rapid evolution at a single locus and can lead to loss of a critical adaptive allele. The decline and loss of this allele will likely hinder current and future restoration efforts, as well as compromise resilience and evolutionary potential. Thus, human-induced phenotypic change can result in rapid loss of important adaptive variation, and conservation action to address human impacts on phenotypic variation will sometimes be necessary to preserve evolutionarily significant biodiversity.

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For example, if phenotypic changes are due to plasticity (i.e., the ability of the same genotype to produce different phenotypes when exposed to different environments), previous characteristics may rapidly reemerge if environmental conditions become favorable (e.g., habitat is restored or new habitat becomes accessible) (18, 19). However, phenotypic change due to genetic evolution (i.e., changes in allele and genotype frequencies across generations) may severely impact the ability to recover previous characteristics (5, 12, 20). In the case of genetic evolution, the ability to recover previous phenotypic characteristics will depend on factors such as the genetic architecture of the affected trait (21). Unfortunately, understanding the genetic basis of phenotypic variation, and thus the potential consequences of human-driven phenotypic change, can be challenging because the genes that influence specific traits in natural populations are usually unknown (22, 23).

The adult migration characteristics of Chinook salmon (*Oncorhynchus tshawytscha*) are a clear example of adaptive phenotypic variation that has been impacted by anthropogenic activities (11, 24, 25). Across the southern part of their coastal (i.e., noninterior) range in North America, Chinook display two primary phenotypes in the characteristics of their spawning migration (26). Premature-migrating Chinook enter freshwater from the ocean in a sexually immature state during the spring, migrate high into watersheds to near their spawning grounds, and hold over the summer in a fasted state while their gonads develop before spawning in the fall. In contrast, mature-migrating Chinook enter freshwater in a sexually mature state in the fall and migrate directly to their spawning grounds to spawn immediately (26). Although a suite of characteristics distinguishes premature- and mature-migrating Chinook (e.g., gamete maturation state and body fat content at freshwater entry, time between freshwater entry and spawning, etc.), freshwater entry date is commonly used as a proxy when more comprehensive measurements are not available (26, 27). Thus, the premature and mature migration phenotypes are commonly referred to as "spring-run" and "fall-run," respectively, which will be the nomenclature used here. The spatial and temporal differences between the two migration types facilitate use of heterogeneous habitats, buffer populations against environmental variability, and provide variation upon which future evolution can act (2, 26, 28).

Many rivers historically hosted large numbers of both phenotypes (29, 30). However, because they rely on clean, cold water throughout hot summer months, spring-run Chinook are more vulnerable than fall-run Chinook to anthropogenic activities that affect river conditions such as logging, mining, dam construction, and water diversion (11, 13, 26, 29, 31). Consequently, in locations where both phenotypes existed historically, the spring-run phenotype has either dramatically declined in relative frequency or disappeared completely since the arrival of Europeans (24, 32). Despite their broad and well-recognized value [e.g., spring-run Chinook play important roles in the indigenous cultures of the Pacific Northwest (33–35), are widely considered to be the most desirable of any salmon for consumption due to their high fat content (36), and transport marine-derived nutrients higher into watersheds than fall-run Chinook (26, 37)], the widespread declines and extirpations of spring-run Chinook have been met with limited conservation concern. Previous research found that coastal (i.e., noninterior) spring-run and fall-run Chinook within a river usually exhibit little overall genetic differentiation and are more closely related to each other than to populations of the same phenotype from other watersheds (38, 39). This was interpreted to suggest the spring-run phenotype could rapidly reemerge from fall-run populations if favored by future conditions (e.g., habitat was restored) (13). Here we investigate the mechanism underlying the dramatic decline of the spring-run phenotype and its future recovery potential.

Results

Rapid Genetic Change from Strong Selection at a Single Locus Explains Phenotypic Shift in Rogue Chinook. As one of the few remaining locations with a significant number of wild spring-run Chinook (40), the Rogue River in Oregon (Fig. 1*A*) presents a prime opportunity to examine the mechanism behind anthropogenically induced changes in Chinook migration characteristics. Before construction of Lost Creek Dam (LCD) in 1977, Chinook entered the upper basin (i.e., crossed the Gold Ray Fish Counting Station [GRS]) almost exclusively in the spring. After dam construction, the Chinook population experienced a phenotypic shift that, by the 2000s, had resulted in a striking increase in the number of individuals entering the upper basin in summer and fall, and a corresponding decrease in the number entering in the spring (Fig. 1*B* and Dataset S1, Table S1) (25). This shift occurred despite the majority of Chinook spawning habitat existing below the dam site (25). Because the dam altered downstream temperature and flow regimes (e.g., *SI Appendix*, Fig. S1) (25), this shift may have resulted from phenotypic plasticity, where postdam environmental conditions cue fish to migrate later. Alternatively, or in addition, the phenotypic shift may have resulted from rapid genetic evolution due to selection caused by postdam conditions.

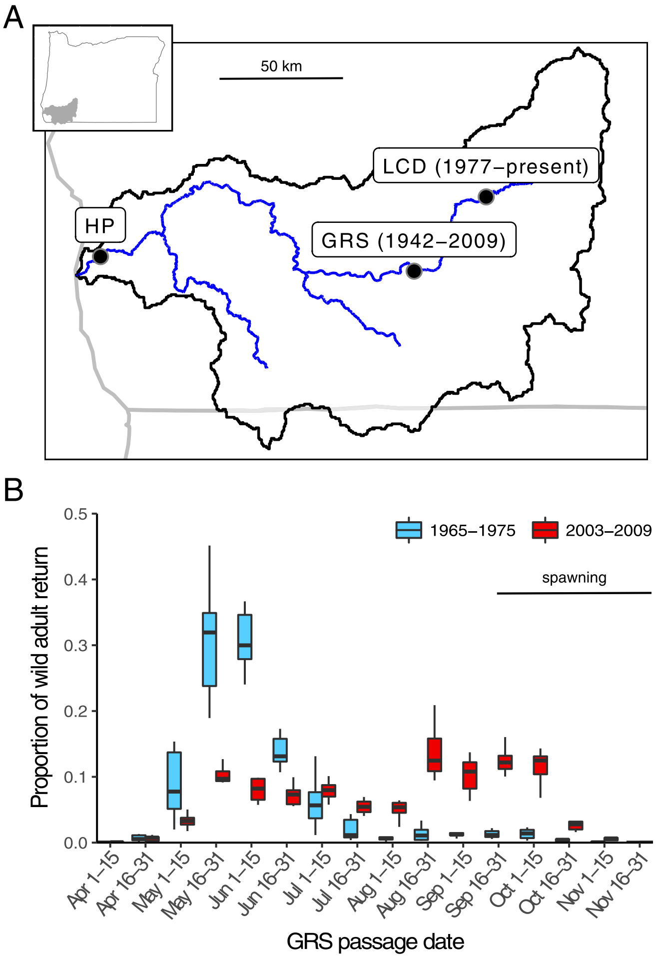

Fig. 1. Phenotypic change in Rogue River Chinook. (*A*) Map of Rogue River; dates indicate presence of features. (*B*) Bimonthly proportion of annual wild adult Chinook return across GRS before (1965–1975; 1968 was excluded due to incomplete data) and after (2003–2009; counts before 2003 included hatchery fish and GRS was removed in 2010) LCD construction; horizontal bar depicts Chinook spawn timing.

To begin investigating the shift in Rogue Chinook migration characteristics, we analyzed 269 fish that crossed GRS during three approximately week-long intervals in late May (n = 88), early August (n = 89), and early October (n = 92). Each fish was genotyped at a locus (the *GREB1L* region) previously found to be associated with migration type (i.e., spring-run or fall-run) across a wide array of Chinook populations (41, 42), using a newly developed marker (*Materials and Methods* and Dataset S1, Tables S2 and S5). Strikingly, the three groups had dramatically different genotype frequencies (Fig. 2*A* and Dataset S1, Table S3). All but one late May fish were homozygous for the allele associated with the spring-run phenotype (hereafter referred to as the spring-run allele), with the single heterozygote passing GRS on the last day of that collection period. The majority of early August fish were heterozygous. The early October group was overwhelming homozygous for the allele associated with the fall-run phenotype (hereafter referred to as the fall-run allele). However, a few early October individuals were heterozygous or homozygous for the spring-run allele. GRS is located ∼200 km from the river mouth (Fig. 1*A*) and thus the heterozygous and homozygous spring-run fish that passed GRS in early October may have entered freshwater earlier but held below GRS for an extended period before passage. We conclude that there is a strong association between *GREB1L* genotype and GRS passage date in Rogue Chinook and that heterozygotes have an intermediate migration phenotype.

To further investigate the association between *GREB1L* and the migration characteristics of Rogue Chinook, we genotyped 38 fish collected in mid-September at Huntley Park (HP; Fig. 1*A*). HP is located on the mainstem Rogue ∼13 km from the river mouth so, unlike GRS samples, HP fish are unlikely to have been in freshwater for an extended period before collection. Strikingly, all HP samples were homozygous for the fall-run allele (Fig. 2*A*), a significantly lower homozygous spring-run/heterozygous frequency than GRS early October samples (P = 0.003; binomial distribution). This suggests that heterozygous and homozygous spring-run fish from GRS in early October likely entered freshwater earlier in the year but held for an extended period below GRS before crossing. We conclude that genotype at the *GREB1L* locus is a better predictor of general migration type (spring-run, fall-run, or intermediate) than passage date at GRS.

We next estimated the total number of fish of each genotype that passed GRS during the year our samples were collected by extrapolating the genotype frequencies across the entire run year. Briefly, we fit the genotype frequencies with sigmoidal curves to estimate the probability that a fish ascending GRS on any specific day would be each of the three possible genotypes (Fig. 2*B*). We then multiplied the observed number of individuals passing on each day by the genotype probabilities for the same day (Fig. 2*C* and Dataset S1, Table S1). Finally, we performed bootstrap resampling of the daily genotype data to determine 95% confidence intervals for this and subsequent analyses. The analysis suggested that, of the 24,332 individuals that passed GRS in 2004 (Dataset S1, Table S1), 8,561 (7,825–9,527) were homozygous for the spring-run allele, 6,636 (5,077–7,798) were heterozygous, and 9,135 (8,124–10,253) were homozygous fall-run. These abundance estimates correspond to homozygous spring-run, heterozygous, and homozygous fall-run genotype frequencies of 0.352 (0.322–0.392), 0.273 (0.209–0.320), and 0.375 (0.334–0.421), respectively, as well as a spring-run allele frequency of 0.488 (0.457–0.518) and a fall-run allele frequency of 0.512 (0.482–0.543). Notably, the estimated homozygous spring-run migration date distribution was strikingly similar to the empirical migration date distribution before LCD construction (Figs. 1*B* and 2*C*), suggesting the predam population was predominantly homozygous spring-run and the migration time of this genotype has not changed since dam construction. This was

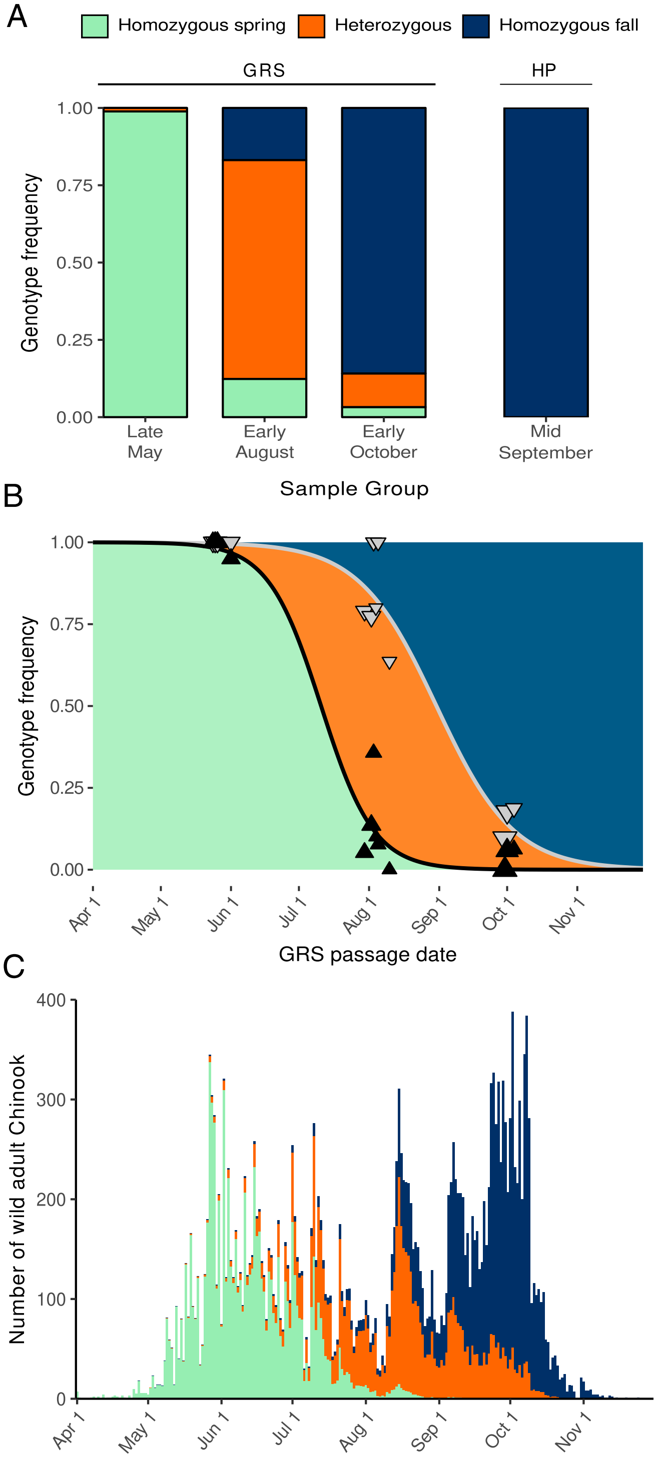

Fig. 2. Genetic basis of adult migration phenotype in Rogue River Chinook. (*A*) Stacked bar graph representing observed *GREB1L* genotype frequencies in GRS and HP sample groups. (*B*) Scatter plot representing observed *GREB1L* genotype frequencies in GRS samples across 13 collection days; triangles represent homozygous spring-run (black) and homozygous spring-run plus heterozygous (gray) genotype frequencies; triangle size is proportional to the number of fish analyzed each day (minimum 10, maximum 42). For fish that pass GRS during a specific time interval (e.g., a single day), the area below the black line represents the expected frequency of the homozygous spring-run genotype, the area between the lines represents heterozygotes, and the area above the gray line represents the homozygous fall-run genotype. (*C*) Stacked bar graph representing number of wild adult Chinook passing GRS in 2004; colors represent estimated proportion of each *GREB1L* genotype.

further supported by an analysis of 36 predam samples collected near the historical late-May/early-June GRS migration peak (Fig. 1*B*), all of which were homozygous for the spring-run allele (*Materials and Methods* and Dataset S1, Table S3). We conclude that the phenotypic shift after dam construction is explained by rapid allele and genotype frequency shifts at the *GREB1L* locus.

To explore selection regimes that could produce this genetic change in such a short time frame (approximately seven generations), we estimated the spring-run allele frequency before LCD and the selection coefficients required to reach the observed 2004 allele frequency under a simple model assuming the spring-run allele was either recessive, dominant, or codominant with respect to fitness (*Materials and Methods*) (21). Under the recessive scenario, heterozygous and homozygous fall-run genotypes have equal fitness (selection coefficients: $s_{FF} = s_{SF} = 0$, $0 \leq s_{SS} \leq 1$). Under the dominant scenario, heterozygous and homozygous spring-run genotypes have equal fitness ($s_{FF} = 0$, $0 \leq s_{SF} = s_{SS} \leq 1$). Under the codominant scenario, heterozygotes have an intermediate fitness ($s_{FF} = 0$, $s_{SF} = 1/2 s_{SS}$, $0 \leq s_{SS} \leq 1$). Applying the genotype probability distribution (Fig. 2*B*) to the predam fish counts (Fig. 1*B*) suggested a predam spring-run allele frequency of 0.895 (0.873–0.919), which the predam sample analysis (discussed above) supports as a reasonable estimate (*Materials and Methods* and Dataset S1, Table S3). Next, the modeling estimated selection coefficients for the homozygous spring-run genotype (s_{SS}) of 0.367 (0.348–0.391), 0.646 (0.594–0.712), and 0.447 (0.424–0.480) under the recessive, dominant, and codominant scenarios, respectively. Furthermore, we explored the potential consequences of continued selection against the spring-run phenotype by extrapolating our modeling into the future. This predicted a spring-run allele frequency in 2100 of 0.106 (0.099–0.112), 3.24×10^{-11} (2.44×10^{-13} to 7.96×10^{-10}), and 0.002 (0.001–0.003) under the recessive, dominant, and codominant scenarios, respectively (Fig. 3). Thus, our modeling demonstrates that selection strong enough to explain the rapid phenotypic and genotypic shifts could lead to loss of the spring-run allele in a relatively short time. We conclude that, under continual selection against the spring-run phenotype, the spring-run allele cannot be expected to persist unless it is recessive with respect to fitness.

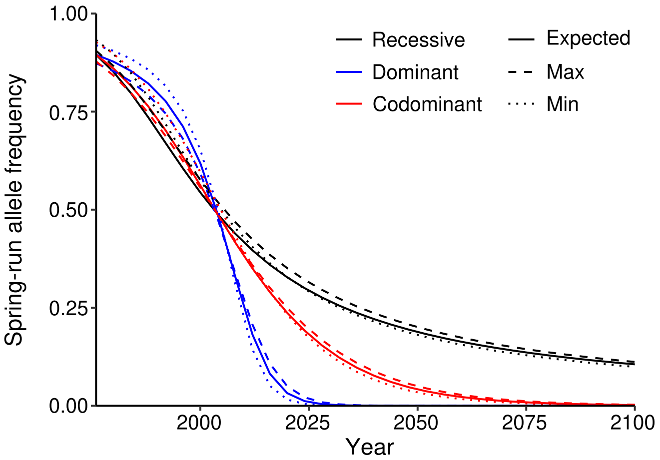

Fig. 3. Selection modeling in Rogue Chinook. Line graph representing the spring-run allele frequency over time under recessive, dominant, and codominant scenarios. Estimated spring-run allele frequencies in 1976 (1 y before LCD construction) and 2004 were used to determine selection coefficients for each scenario [recessive: $s_{FF} = s_{SF} = 0$, $s_{SS} = 0.367$; dominant: $s_{FF} = 0$, $s_{SF} = s_{SS} = 0.646$; codominant: $s_{FF} = 0$, $s_{SF} = 1/2(s_{SS})$, $s_{SS} = 0.447$]. The modeling assumes random mating and no genetic drift.

Ancient and Contemporary Klamath Chinook Reveal Hindered Spring-Run Restoration Potential. The Klamath River in northern California and southern Oregon (Fig. 4) presents an opportunity to empirically examine the consequences of longer-term selection against the spring-run phenotype. The Klamath historically hosted hundreds of thousands of adult spring-run Chinook annually, with the spring-run phenotype possibly exceeding the fall-run phenotype in frequency (30). While the fall-run phenotype remains relatively abundant (i.e., tens to hundreds of thousands of adults per year) (43), dam construction and habitat degradation beginning in the late 1800s led to severe declines in the spring-run phenotype, with virtually complete loss of wild spring-run Chinook in the mainstem and tributaries except the Salmon River (Fig. 4) (24, 44). In the last decade, Salmon River spring-run Chinook have ranged from ~200–1,600 individuals (45) and are expected to be extirpated within 50 y (24). In 2021, the largest-scale dam removal project in history is scheduled to remove four dams in the upper basin (46) and reopen hundreds of miles of historical Chinook habitat inaccessible since 1912 (47) (Fig. 4). This dam removal provides an opportunity unprecedented in scale to restore extirpated populations, including spring-run Chinook (48). However, while historical documentation supports the presence of early-migrating Chinook in the upper Klamath (47), the extent to which above-dam populations relied on the same spring-run allele as the Rogue (discussed above) and other contemporary Chinook populations (41) (*Materials and Methods* and Dataset S1, Table S5) is unknown. Furthermore, since most contemporary Klamath populations have lost the spring-run phenotype, it is unclear which, if any, are acting as reservoirs of the spring-run allele and therefore could serve as a source population for restoration of spring-run Chinook in the upper basin.

To investigate the genetic composition of historical upper Klamath Chinook, we genotyped nine Chinook samples collected from four archaeological sites in the upper basin known to be historically important fishing places for Klamath peoples (49) (Fig. 4). The samples ranged in age from post-European contact to ~5,000 y old and, based on the presence of all body parts in the archaeological sites, were likely caught locally as opposed to being acquired through trade (49–51) (Table 1). Strikingly, three of the locations had only homozygous spring-run samples, while the remaining location had only homozygous fall-run samples (Table 1). The spring-run sample locations are known to have been occupied by humans in the spring or throughout the year and are also near major cold-water input sources [suitable oversummering habitat for spring-run Chinook (52)], whereas the fall-run samples came from a location with a documented historical fall fishery (53). We conclude that the upper basin harbored the same allelic variants as contemporary populations, and these spring-run alleles are expected to be necessary for restoration of the spring-run phenotype in the upper basin (discussed above) (41).

To test if lower (i.e., below-dam) Klamath populations that have lost the spring-run phenotype are serving as reservoirs of the spring-run allele, we genotyped juvenile Chinook collected from the Shasta River (Fig. 4) throughout the juvenile outmigration season in 2008–2012 (Dataset S1, Table S4) (54). The Shasta, where spring-run Chinook were last observed in the 1930s (30), is a major Klamath tributary that shares many environmental characteristics with the habitat above the dams (e.g., large spring water input sources, dry climate, etc.) (55). Thus, Shasta Chinook may contain additional adaptive variation suitable for the upper Klamath, which makes them an attractive restoration stock candidate (56). Strikingly, out of the 437 successfully genotyped individuals, only 2 were heterozygous and all others were homozygous for the fall-run allele, corresponding to a spring-run allele frequency of 0.002 (binomial distribution 95% CI: 3×10^{-4} to 0.008; Table 2). This is at least an order of

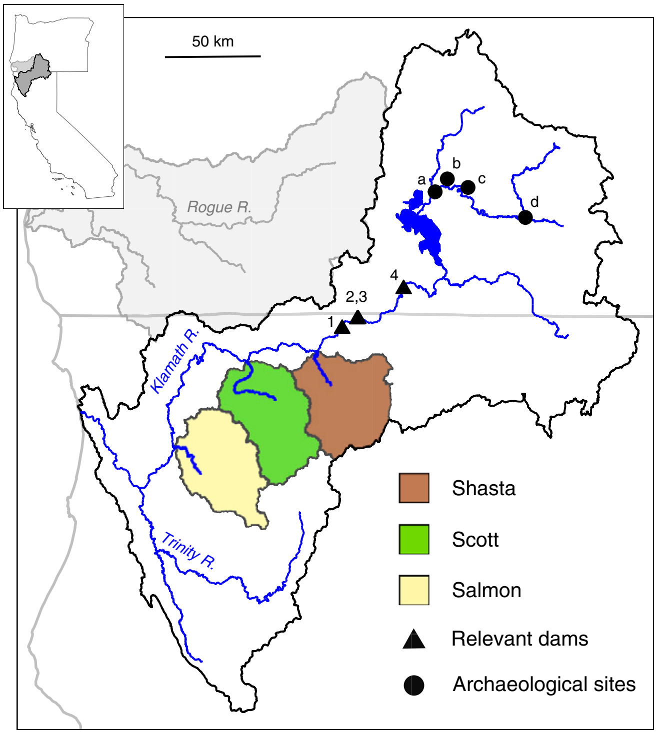

Fig. 4. Map of the Klamath Basin. Klamath dams scheduled for removal in 2021: 1, Iron Gate; 2, Copco 1; 3, Copco 2; and 4, J. C. Boyle. Archaeological site locations of ancient samples: a, Williamson River Bridge; b, Bezuksewas Village; c, Kawumkan Springs Midden; and d, Beatty Curve. R., River.

magnitude below the expected frequency if the spring-run allele was recessive with respect to fitness (*Discussion*; e.g., Fig. 3) (21) and, interestingly, very similar to the codominant scenario in our Rogue Chinook modeling (0.002 vs. 0.002; Fig. 3) after a similar period of selection against the spring-run phenotype (late 1800s-early 2000s vs. 1977–2100). Given the recent annual adult returns to the Shasta River (mean during the years our samples were spawned: 5486) (57) and N_e/N ratios in Chinook (58), such frequencies suggest the spring-run allele is highly vulnerable to complete loss through continued selection and/or genetic drift (*Discussion*). We conclude the contemporary Shasta Chinook population cannot be considered a sustainable reservoir of the spring-run allele.

To test if locations with disparate environmental conditions are acting as reservoirs of the spring-run allele, we genotyped Chinook juveniles collected over a similar time range in the Scott River (Fig. 4 and Dataset S1, Table S4), a Klamath tributary that exhibits a hydrologic regime driven by surface water, which is typical of the lower Klamath basin but very different from the Shasta River (55). The spring-run phenotype was last observed in the Scott River in the 1970s (30). We also genotyped 116 juveniles from the Salmon River (see above; Fig. 4 and Dataset S1, Table S4) as a positive control. Out of 425 successfully genotyped Scott samples, we found only two heterozygotes (spring-run allele frequency: 0.002; binomial distribution 95% CI: 3×10^{-4} to 0.008), whereas the Salmon River samples had an overall spring-run allele frequency of 0.20 (Table 2), corresponding well with spring-run phenotype frequency estimates based on annual dive and carcass surveys in the Salmon River (45, 59). We conclude the Scott River is also not acting as a sustainable reservoir of the spring-run allele, and diverse environments are susceptible to rapid loss of the spring-run allele upon extirpation of the spring-run phenotype.

Discussion

Phenotypic variation in natural populations facilitates resilience in heterogeneous or variable environments (2, 5). The genetic architecture of natural phenotypic variation, though usually unknown, is typically assumed to be complex (i.e., polygenic and influenced by the environment) (60). A recent study identified a single locus (the *GREB1L* region) associated with migration type in Chinook as well as the closely related species steelhead (*Oncorhynchus mykiss*) (41). However, the relatively low marker resolution and poor phenotypic information in the Chinook analysis obscured the strength of association and phenotype of heterozygotes (41). Our analysis of samples with more detailed phenotypic information [i.e., specific migration dates at GRS and HP (*Results* and Dataset S1, Table S3) as well as the lower South Fork Trinity (*Materials and Methods* and Dataset S1, Table S5)] using a new marker identified through a high-resolution, multipopulation analysis of *GREB1L* (*Materials and Methods* and Dataset S1, Tables S2 and S5) suggests that (*i*) the association of migration characteristics with variation at *GREB1L* is extremely robust and (*ii*) heterozygotes have an intermediate migration phenotype (Fig. 2*A*). Therefore, while phenotypic variation within each genotype (e.g., precise freshwater entry and spawning dates) is yet to be explained, general migration type (i.e., premature/spring-run or mature/fall-run) appears to have a relatively simple genetic architecture (i.e., a locus of very large effect). Furthermore, the association of a single haplotype with the spring-run phenotype in diverse locations (*Materials and Methods* and Dataset S1, Table S5) supports previous evidence that spring-run alleles arose from a single evolutionary event and cannot be expected to readily reevolve (41, 61). Thus, important natural phenotypic variation can be underpinned by relatively simple modes of inheritance and rare allelic evolutionary events.

Selection results from the balance between benefits and costs of specific phenotypes (62), and anthropogenic habitat alteration can potentially disrupt this balance (9, 12, 63, 64). The large and rapid decline in the Rogue spring-run phenotype and allele frequency suggests strong selection against spring-run Chinook after LCD construction. Furthermore, our modeling demonstrates that such selection, if sustained, could rapidly result in complete loss of the spring-run allele. A main benefit of the spring-run phenotype is thought to be access to exclusive temporal and/or spatial habitat, while a major cost is reduced gametic investment (e.g., smaller egg size) because energy must be dedicated to maintenance and maturation while fasting in freshwater (26, 65). River flow regimes can be a major driver of life history evolution in aquatic systems (12, 64), and LCD altered downstream temperature and flow in a way that may allow fall-run Chinook access to spawning habitat that was previously exclusive to spring-run Chinook (25). An analysis of carcass samples from the Rogue revealed substantial spatial and temporal overlap in spawning distributions of all three genotypes (*SI Appendix*, Fig. S2 and Dataset S1, Table S3), supporting the hypothesis that anthropogenically induced habitat alterations have reduced the historical benefit of the spring-run phenotype, contributing to its decline. Regardless of exact mechanisms, our results provide a clear example where anthropogenic factors induced rapid phenotypic change through genetic evolution as opposed to phenotypic plasticity.

Population genetics theory and our selection modeling predicts that, for loci with a large phenotypic effect, alleles promoting negatively selected phenotypes will be eliminated from a population unless they are masked in the heterozygous state (i.e., recessive with respect to fitness) (21). The intermediate migration phenotype of heterozygotes, in combination with typical lower river conditions at intermediate times (i.e., conditions inhospitable to salmonids), suggests their fitness will be at least somewhat different, and likely lower, than that of fall-run Chinook in most

Table 1. **Ancient upper Klamath Chinook sample information and genotyping results, listing Simon Fraser University (SFU) sample identification number and Oregon state site numbers**

SFU sample ID	Site name (no.)	Age*	Genotype
SBC01	Beatty Curve (35KL95)	AD 1860–20th century	Homozygous fall-run
SBC13	Beatty Curve (35KL95)	AD 1860–20th century	Homozygous fall-run
SBC14	Beatty Curve (35KL95)	AD 1860–20th century	Homozygous fall-run
SBC26	Bezuksewas Village (35KL778)	AD 1390–1860	Homozygous spring-run
SBC53	Bezuksewas Village (35KL778)	AD 1390–1860	Homozygous spring-run
SBC36	Kawumkan Springs Midden (35KL9-12)	Unknown (likely before AD 1860)	Homozygous spring-run
SBC33	Kawumkan Springs Midden (35KL9-12)	3160–3110 BC	Homozygous spring-run
SBC42	Williamson River Bridge (35KL677)	450 BC–20th century	Homozygous spring-run
SBC43	Williamson River Bridge (35KL677)	450 BC–20th century	Homozygous spring-run

*See *Materials and Methods.*

locations (66). Therefore, where the spring-run phenotype is lost, spring-run alleles cannot be expected to be maintained in the heterozygous state. This prediction is empirically supported by our results from the Shasta and Scott Rivers where, based on adult run size estimates during the years our samples were spawned (~5,000 per year in each river) (57, 67), the observed spring-run allele frequency (0.002) would correspond to an average of ~20 heterozygous adults per year in each river. Given that adult Chinook have highly variable reproductive success (58), such a low frequency makes the spring-run allele extremely vulnerable to complete loss through genetic drift regardless of selection (21) (something that may conceivably have already occurred, given our samples were collected several years ago). Notably, while habitat alterations extirpated the spring-run phenotype from the Shasta and Scott, the total Chinook census sizes (i.e., adults of any migration type) of both rivers are considered robust (57, 67). Thus, both theory and empirical evidence suggest heterozygotes cannot be expected to act as a sustainable reservoir for spring-run alleles, and important adaptive variation can be vulnerable to loss from human impacts regardless of total population size.

Adaptive variation is likely important to the success of species restoration efforts (56, 68). The planned removal of Klamath dams provides an opportunity to restore Chinook to historical habitat that is unprecedented in scale and provides a lens through which to evaluate the challenges of recovering the spring-run phenotype. Historical documentation (47) and our analysis of ancient samples suggest both migration types existed above the dams. Furthermore, an evaluation of the upper basin environment suggests habitat suitable for both phenotypes will be available after dam removal (48, 52, 69), with some locations likely favoring the earlier migration and spawning times of the spring-run phenotype (52). While abundant Klamath fall-run Chinook are likely to naturally recolonize the upper basin, the current scarcity of the spring-run phenotype and allele in the Klamath will likely hinder natural recolonization of spring-run Chinook. Similarly, natural recolonization via straying from out-of-basin populations is improbable on short timescales and tenuous on longer timescales given the ongoing declines and extirpations of spring-run Chinook throughout their range. Human-facilitated restoration may also be challenged by limited options for appropriate source populations. The Shasta River's environmental similarities with the upper basin (55, 69) would have made it an attractive candidate if spring-run alleles were more abundant (52, 56, 70). Salmon River spring-run Chinook are severely depressed in number (24, 45, 52) and may lack other adaptive variation important for the upper basin due to the major environmental differences between the locations (55, 70). Spring-run alleles are present in a within-basin hatchery population (i.e., Trinity River Hatchery), but hatchery salmonids are partially domesticated, have reduced reproductive success in the wild, and can negatively impact wild populations (71–74). Introducing an out-of-basin wild stock [e.g., Rogue spring-run Chinook, the most proximate spring-run population to the Klamath (Figs. 1*A* and 4 and refs. 41 and 52)] could be an option but may also be challenged by incompatibilities stemming from local adaptation (52, 70). Given that wild spring-run Chinook are expected to disappear from the lower Klamath within 50 y and are declining across their range (24), the current challenges of restoring spring-run Chinook upon Klamath dam removal are a preview of even greater challenges that will be faced in future spring-run Chinook restoration projects if the spring-run phenotype continues to decline. Thus, the decline and loss of adaptive variation due to anthropogenic habitat alterations can hinder the ability to recover previous characteristics and restore wild populations.

Humans impact phenotypic variation across taxa and traits (9, 10) through diverse means (e.g., hunting and fishing, habitat modification, climate change, etc.; refs. 20, 64, and 75–78). While a substantial body of work has discussed the theoretical consequences of human-driven selection (5, 10, 12, 15, 18, 20, 75), empirical explorations have been challenged by the historical difficulty of uncovering the genetic basis of natural phenotypic variation. Although recent work has begun to characterize the genetic basis of phenotypic variation and identified large-effect loci in species of conservation concern (79–84), empirical work evaluating the consequences of anthropogenic selection for the long-term persistence and/or recovery potential of adaptive variation is still rare. The results presented here demonstrate that human-induced phenotypic change can have severe consequences

Table 2. **Klamath Chinook smolt information and genotyping results**

River	Date last spring-run Chinook observed	No.	Year(s)	Homozygous spring-run	Heterozygous	Homozygous fall-run	Spring-run allele frequency
Shasta	1930s*	437	2008–2012	0	2	435	0.002 (3×10^{-4} to 0.008)[†]
Scott	1970s	425	2007–2013	0	2	423	0.002 (3×10^{-4} to 0.008)[†]
Salmon	Present	116	2017	14	19	83	0.20

*Spring-run Chinook were still observed just upstream of the Shasta River mouth at Iron Gate Dam into the 1970s.

[†] Ninety-five percent CI calculated using binomial probability distribution.

with respect to the ability of previous variation to reemerge. Given the broad impacts of anthropogenic activities on phenotypic diversity, future research examining the consequences for the persistence and recovery of variation in other species will be important for informing conservation and management actions.

Although this study provides important insights into the genetics and conservation of spring-run Chinook, additional information would be useful to further inform conservation and restoration actions. In the Klamath, more extensive evaluation of the adaptive suitabilities of potential restoration source stocks (e.g., Salmon, Trinity, and Rogue River spring-run Chinook) would be valuable. On a broader scale, work characterizing the distribution of spring-run alleles, especially in populations that appear to lack the spring-run phenotype, is needed to identify if and where the genetic potential for the phenotype still exists (e.g., in heterozygotes) (85). Ongoing monitoring of allele frequencies will likely also be essential, as spring-run alleles may be present but in decline. Importantly, a better understanding of the ecology (i.e., spawning and rearing locations), phenotype (i.e., range of river entry and spawning dates, fecundity, etc.), and fitness (i.e., relative reproductive success) of each genotype would be useful for understanding selection mechanisms and targeting conservation strategies, as would a thorough exploration of the roles hatchery fish may play in the decline or persistence of spring-run alleles in wild populations. Given that spring-run Chinook have historically been prominent on the southernmost edge of the species range (26), the phenotype may carry substantial adaptive importance for more northern locations under climate change (86). A more extensive evaluation of this would be valuable. Finally, although the genetic marker used here is currently the best available to distinguish between migration types (see Dataset S1, Table S5 for marker comparison), continued marker development [e.g., identification of the causative polymorphism(s)] would reduce the potential for misclassification of migration type due to factors such as rare recombination events.

The combination of results from this study provides important insights into the mechanisms and consequences of phenotypic change induced by anthropogenic habitat alteration. First, our results demonstrate that natural phenotypic variation can have a relatively simple genetic architecture and that anthropogenically induced phenotypic change can be caused by rapid genetic evolution from strong selection at individual loci. Furthermore, our results (both modeled and empirical) demonstrate such a situation can lead to the rapid loss of important adaptive alleles, including from populations that are healthy from a total population size perspective. In cases where adaptive alleles are the product of mutational events that are very rare from an evolutionary perspective [such as the spring-run allele in Chinook (41, 42)], their loss will create a major challenge for future restoration as well as limit resilience and evolutionary potential. Taken together, our results highlight the need to conserve and restore critical adaptive variation before the potential for recovery is lost.

Materials and Methods

***GREB1L* Marker Discovery.** Previous research identified a significant association between variation in the *GREB1L* region and adult migration type (i.e., premature or mature) in both Chinook and steelhead (*O. mykiss*) (41, 42, 87). Although the strongest associated SNP in Chinook [position 569200 on scaffold79929e (41)] had a large allele frequency difference between premature and mature migrating populations in several locations (41), this association was notably weaker than observed in steelhead. We reasoned the weaker association could have resulted from technical reasons (e.g., lower SNP resolution of the Chinook analysis) as opposed to biological reasons (e.g., smaller influence of the *GREB1L* locus in Chinook compared with steelhead).

We therefore used capture baits to isolate and sequence the *GREB1L* region in 64 Chinook samples (across eight locations in California, Oregon, and Washington; Dataset S1, Table S5) from the previous association study (41) for additional SNP identification and association testing. The two most strongly associated SNPs identified by this process (positions 640165 and 670329 on scaffold79929e) were ~30 kb apart just upstream of *GREB1L* and revealed much stronger associations than the most strongly associated SNPs from the previous study (41) (Dataset S1, Table S5). These results confirm that the relatively weak association between *GREB1L* and migration type previously observed in Chinook (compared with steelhead) (41) was due to lower SNP resolution as opposed to a smaller influence on phenotype.

SNP Assay Design and Validation. We designed TaqMan-based genotyping assays for the two newly discovered SNPs to facilitate rapid and inexpensive genotyping of the *GREB1L* locus across large numbers of samples. Approximately 300 bp of Chinook sequence surrounding each SNP (Dataset S1, Table S2) was submitted to the Custom TaqMan Assay Design Tool (Applied Biosystems) to generate primer and probe sequences for each SNP. Additional polymorphic sites in the surrounding sequence identified in the capture sequencing were masked to avoid primer or probe design across these sites. Assays were run using 5 μL 2× TaqMan Genotyping Master Mix, 0.5 μL 20× genotyping assay [final concentrations of 900 nM (primers) and 200 nM (MGB probes)], 2.5 μL DNA-grade water, and 2 μL sample DNA for each reaction. Reporter dyes were Vic and Fam. Each 96-well SNP assay plate also contained one positive control for each genotype (taken from samples used in capture sequencing) and two negatives controls substituting water or low TE (0.1 mM EDTA and 10 mM Tris, pH 8.0) for DNA. No negative controls ever amplified. Each SNP assay was run separately (not multiplexed) for each sample. The assays were run on either a Chromo4 or QuantStudio-3 Real Time PCR machine for 10 min at 95 °C followed by 40 cycles of 15 s at 95 °C and 1 min at 58–59 °C (snp640165) or 62–64 °C (snp670329).

SNP assays were validated with the samples used for capture sequencing. All results were consistent with sequencing-based genotype calls (Dataset S1, Table S5). Our genotyping results from GRS and HP (Fig. 2*A* and Dataset S1, Table S3) serve as further validation of the assays in the Rogue River. For additional validation in the Klamath, we genotyped 62 samples from Chinook with known migration dates through a weir on the lower South Fork Trinity River (Dataset S1, Table S5). All South Fork Trinity samples phenotyped as spring-run (i.e., weir passages dates between mid-May and end of July) were homozygous for the spring-run allele except for a single heterozygote collected on July 31. All samples phenotyped as fall-run (i.e., weir passages dates between mid-October and mid-November) were homozygous for the fall-run allele (Dataset S1, Table S5).

Contemporary Sample Collection and DNA Extraction. Rogue GRS samples were obtained from wild Chinook salmon, defined as lacking an adipose fin clip, that returned to spawn in the Rogue River during 2004. Fish were trapped by Oregon Department of Fish and Wildlife (ODFW) personnel at a fish-count station (GRS) located at Gold Ray Dam (erected in 1941). Tissue was sampled from the operculum of each fish and placed in 100% ethanol for storage and subsequent DNA extraction using Qiagen DNeasy kits following the manufacturer's protocols. Following sampling, fish were released unharmed upstream of the dam barrier. Approximately 300 samples were evenly obtained across three temporal sampling windows (May 24 to June 1; July 30 to August 10; and September 30 to October 4) that targeted spring, intermediate, and fall runs.

Rogue HP samples were collected from wild Chinook caught in beach seines near HP in September 2014 (Dataset S1, Table S3). Rogue pre-LCD samples were collected in the lower river during May of 1975 and 1976 (Dataset S1, Table S3) and stored in the ODFW scale archive. Rogue carcass samples were collected during ODFW spawning surveys of the upper Rogue in 2014 (Dataset S1, Table S3). Juvenile Chinook from the Salmon, Shasta, and Scott Rivers in the Klamath Basin were caught in screwtraps during smolt outmigration across several years (Dataset S1, Table S4) (54). South Fork Trinity samples were collected from live adult Chinook during passage through Sandy Bar weir, except for three samples that were collected at Forest Glen (Dataset S1, Table S5). Fin clip (HP, Rogue carcass, and Salmon) or scale (Rogue pre-LCD, Shasta, and Scott) samples were collected, dried on filter paper, and stored at room temperature. DNA was extracted using a magnetic bead-based protocol (88) and stored at −20 °C.

Archaeological Sample Collection and DNA Extraction. The archaeological samples were recovered from archaeological excavation projects led by research teams from the University of Oregon Museum of Natural and Cultural History between the late 1940s and the late 2000s (49, 89). The four sites represent fishing camps or year-round villages occupied by ancestral people to the Klamath Tribes of Oregon (Table 1 and Dataset S1, Table S4). Three sites are located on the Sprague River: Kawumkan Springs Midden (90), Beatty Curve (89), and Bezuksewas Village (91). A fourth, Williamson River

Bridge (92), is located near the confluence of the Williamson and Sprague Rivers (Fig. 4). The sites range in age from 7,500 y ago to the early 20th century (49). Because of severe stratigraphic disturbance by burrowing rodents, the materials can typically only be assigned to very broad time periods (Table 1 and Dataset S1, Table S4). Deposits were assigned to AD 1860 or later based on presence of artifacts of Euro-American origin, as AD 1860 marks the establishment of Fort Klamath and time of sustained Euro-American contact in the upper Klamath Basin. Klamath people continued to fish and occupy the Beatty Curve and Williamson River Bridge site locations into the 20th century, so the end date is uncertain. All other ages were based on multiple radiocarbon samples (49), calibrated using OxCal v4.2 (93).

Previous projects (49) assigned the fish remains to the finest taxon possible using modern reference skeletons from known species. To obtain species-level identification, a sample of salmonid remains was sent to the dedicated Ancient DNA Laboratory in the Department of Archaeology at Simon Fraser University, Burnaby, BC, Canada. Twelve vertebra samples (nine Chinook and three steelhead as controls) were included in this study (Dataset S1, Table S4). Samples were chemically decontaminated through submersion in commercial bleach (4–6% sodium hypochlorite) for 10 min, rinsed twice with ultrapure water, and UV-irradiated for 30 min each on two sides. Bones were crushed into powder and incubated overnight in a lysis buffer (0.5 M EDTA, pH 8.0, 0.25% SDS, and 0.5 mg/mL proteinase K) in a rotating hybridization oven at 50 °C. Samples were then centrifuged and 2.5–3.0 mL of supernatant from each sample was concentrated to <100 μL using Amicon Ultra-4 centrifugal filter devices (10 kDa, 4 mL; Millipore). Concentrated extracts were purified using QIAquick spin columns based on previously developed methods (94, 95); 100 μL of DNA from each sample was eluted from QIAquick columns for PCR amplifications.

Species identification was accomplished by targeting salmonid mitochondrial d-loop (249 bp) and cytochrome *b* (cytb) (168 bp) fragments as previously described (96). Successfully amplified products were sequenced at Eurofins MWG Operon Ltd. using forward and/or reverse primers. The resulting sequences were compared with GenBank reference sequences through the BLAST application to determine their closest match, and species identifications were confirmed through multiple alignments of the ancient sequences and published salmonid reference sequences conducted using ClustalW (97) through BioEdit (98), as well as the construction of neighbor-joining phylogenetic trees using Kimura's 2-parameter model in the Mega 6.0 software program (99). Nine of the 12 samples were identified as Chinook (Dataset S1, Table S4) and the remaining three as steelhead.

Rogue and Contemporary Klamath Genotyping. After DNA extraction, samples were genotyped using the assays (snp640165 and snp670329; Dataset S1, Table S2) and qPCR protocol described above. All samples were tested at both SNPs, and a genotype call (homozygous spring-run, heterozygous, or homozygous fall-run; Dataset S1, Tables S3 and S4) was made only if both SNPs were successfully genotyped and consistent with each other. The causative polymorphism(s) in the *GREB1L* region are currently unknown, so requiring successful and consistent calls at both associated SNPs provides greater confidence that the genotype (homozygous spring-run, heterozygous, or homozygous fall-run) was not miscalled due to biological factors such as rare recombination events and is more conservative than using a single SNP. Of the 1,390 samples tested from live-caught fish, 1,333 (95.9%) successfully genotyped at both SNPs, 31 (2.2%) failed at one SNP, and 26 (1.9%) failed at both SNPs. Of the 96 Rogue River carcass samples tested, 86 (89.6%) successfully genotyped at both SNPs, 2 (2.1%) failed at one SNP, and 8 (8.3%) failed at both SNPs. Of the successful live and carcass samples (1,419 total), 1,406 (99%) had the same genotype call at both SNPs, indicating near perfect linkage disequilibrium (LD) between the SNPs. The remaining 13 samples [all from the Rogue (2.9% of successfully genotyped Rogue samples) and mostly from the GRS August group] had a homozygous genotype at one SNP and a heterozygous genotype at the other (Dataset S1, Table S3). Because we do not know which, if either, SNP is in stronger LD with the causative polymorphism(s), these samples were called as ambiguous (Dataset S1, Table S3) and excluded from further analyses.

Ancient Klamath Genotyping. Multiple sealed aliquots of extracted ancient DNA from 12 archaeological samples were shipped from Simon Fraser University to the University of California, Davis on dry ice. Nine samples were from Chinook and the remaining three were from steelhead, which are known to have the same alleles as fall-run Chinook at the two SNPs based on the *O. mykiss* reference genome (100). Genotyping was conducted under blinded conditions with respect to species, location, and age. SNP assays were run using 10 μL 2× TaqMan Genotyping Master Mix, 1 μL 20× genotyping assay [final concentrations of 900 nM (primers) and 200 nM (MGB probes)], 5 μL DNA-grade water, and 4 μL of sample DNA diluted in low TE (either 1:10 or 1:50) for each reaction. The assays were run on a QuantStudio-3 Real Time PCR machine for 10 min at 95 °C followed by 80 cycles of 15 s at 95 °C and 1 min at 58 °C (snp640165) or 64 °C (snp670329). Fluorescence after each amplification cycle was measured and checked to prevent erroneous calls due to high cycle number. All plates contained positive controls for each genotype diluted at ratios similar to the unknown samples and at least 12 negative controls substituting the low TE used in sample dilutions in place of DNA. No amplification was ever observed in a negative control in either the ancient sample plates or any plates containing contemporary samples. All results were replicated using separately sealed aliquots on different days. Due to the extremely high LD in contemporary samples and the precious nature of the ancient samples, genotypes were called even if only one SNP was successfully genotyped (Dataset S1, Table S4). Requiring both SNPs to be successfully genotyped would have reduced the number of ancient Chinook samples with a migration type call from nine to five (two fall-run and three spring-run; Dataset S1, Table S4) but would not have altered our conclusions.

Curve Fitting and Selection Modeling. Sigmoidal curves were fit to the genotype frequencies measured for each collection day at GRS (Fig. 2*B* and Dataset S1, Table S3). The curves were fit using the nonlinear least squares (nls) function in R (101) for a sigmoidal model, optimizing for b and m values: $S = 1/(1 + e^{-b(x - m)})$. The R command used was `nls(gf~1/(1 + exp(−b * (x − m))), weights = w, start = list(b = (−0.01), m = 90))` where gf was either a list of the homozygous spring-run or homozygous spring-run plus heterozygous frequencies (a.k.a. 1 - homozygous fall-run frequency) with each frequency corresponding to a specific sample collection day, x was a list of numeric dates (April 1 was set to day 1) corresponding to each collection day, and w was the number of samples from each day. The resulting equations represent the estimated probability of each genotype on any given day (Fig. 2*B*), and were applied to daily empirical GRS fish counts from 2004 to estimate allele frequencies in 2004.

Pre-LCD allele frequencies were estimated by applying the genotype probability distribution calculated from the 2004 GRS samples (Fig. 2*B*) to the average biweekly fish counts (using mean probability across the biweekly bin) in the decade before LCD construction (Fig. 1*B*, see ref. 25) and resulted in a pre-LCD spring-run allele frequency estimate of ∼90% (*Results*). This approach was used because a pre-LCD sample set adequate to perform a direct estimate of the pre-LCD allele frequencies (e.g., pre-LCD samples collected at GRS throughout the migration season) was not available. However, this approach assumes that the relationship between *GREB1L* genotype and GRS passage date was not substantially different pre- and post-LCD. If this assumption is inaccurate (e.g., the association of *GREB1L* with GRS passage date was weaker in the pre-LCD environment), the pre-LCD population may have had a spring-run allele frequency significantly lower than 90%.

We investigated this possibility by genotyping 36 pre-LCD adult Chinook sampled in May (mean date May 20) from the lower Rogue (mean river mile 17) at the *GREB1L* locus (Dataset S1, Table S3). Based on measured migration rates of Rogue Chinook (25), these fish would likely have passed GRS near or somewhat after the pre-LCD migration peak in late May/early June (Fig. 1*B*). Strikingly, all 36 samples were homozygous for the spring-run allele (Dataset S1, Table S3). This demonstrates that pre-LCD individuals that passed GRS around the spring migration peak overwhelmingly contained the spring-run allele and, since very few pre-LCD individuals passed GRS later in the year, suggests our pre-LCD spring-run allele frequency is unlikely to be an overestimate. Furthermore, because the curves are fit to genotype frequencies from post-LCD conditions where heterozygotes are likely more frequent, the pre-LCD allele frequency results likely underestimate the true spring-run allele frequency before LCD. Thus, the true change in allele frequency after LCD is probably somewhat greater than what is estimated here, and therefore our estimated allele frequencies and selection coefficients are likely conservative.

The strength of selection against the spring-run phenotype [i.e., the homozygous spring-run selection coefficient (s_{SS})] was estimated by calculating values of s_{SS} that explain the estimated change in spring-run allele frequencies between pre-LCD and 2004 using the equation $p' = (s_{SS}\,p^2 + s_{SF}\,p(1 - p)/(s_{SS}\,p^2 + s_{SF}\,2p(1 - p) + s_{FF}\,(1 - p)^2)$ (21), where s_{xx} is the selection coefficient of each genotype, p is the spring-run allele frequency in the current generation, and p′ is the spring-run allele frequency in the next generation. The estimated pre-LCD spring-run allele frequency was used as the starting value of p, and the equation was run recursively using the p′ value from the current run as the next value of p to find values of s_{SS} that resulted in the estimated 2004 spring-run allele frequency after seven generations (assuming 4-y generations). Calculations were conducted under three relative fitness scenarios: recessive ($s_{SF} = s_{FF}$), dominant ($s_{SS} = s_{SF}$), and codominant ($s_{SS} = 2s_{SF}$). The homozygous fall-run genotype was always assumed to have the lowest selection coefficient ($s_{FF} = 0$). This approach assumes Hardy–Weinberg Equilibrium (HWE), which is probably violated because the slightly earlier mean spawning date of spring-run Chinook likely creates some level of assortative mating (e.g., Fig. 2*C* and *SI Appendix*, Fig. S2). Under assortative mating, the overrepresentation of homozygous spring-run individuals could lead to an even more rapid decrease in the spring-run allele frequency because homozygous spring-run experiences the strongest selection in our modeling. Thus, assuming HWE likely produces conservative selection coefficient and future allele frequency estimates.

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SCIENCE ADVANCES | RESEARCH ARTICLE

EVOLUTIONARY GENETICS

The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation

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The delineation of conservation units (CUs) is a challenging issue that has profound implications for minimizing the loss of biodiversity and ecosystem services. CU delineation typically seeks to prioritize evolutionary significance, and genetic methods play a pivotal role in the delineation process by quantifying overall differentiation between populations. Although CUs that primarily reflect overall genetic differentiation do protect adaptive differences between distant populations, they do not necessarily protect adaptive variation within highly connected populations. Advances in genomic methodology facilitate the characterization of adaptive genetic variation, but the potential utility of this information for CU delineation is unclear. We use genomic methods to investigate the evolutionary basis of premature migration in Pacific salmon, a complex behavioral and physiological phenotype that exists within highly connected populations and has experienced severe declines. Strikingly, we find that premature migration is associated with the same single locus across multiple populations in each of two different species. Patterns of variation at this locus suggest that the premature migration alleles arose from a single evolutionary event within each species and were subsequently spread to distant populations through straying and positive selection. Our results reveal that complex adaptive variation can depend on rare mutational events at a single locus, demonstrate that CUs reflecting overall genetic differentiation can fail to protect evolutionarily significant variation that has substantial ecological and societal benefits, and suggest that a supplemental framework for protecting specific adaptive variation will sometimes be necessary to prevent the loss of significant biodiversity and ecosystem services.

INTRODUCTION

Invaluable economic, ecological, and cultural benefits are being lost worldwide as biodiversity decreases due to human actions (*1*–*3*). Legislation that provides a framework to protect unique species and population segments below the species level exists in many countries throughout the world (*4*, *5*). Protection is achieved by assessing the health of a defined conservation unit (CU), and if the unit is at risk, attempts are made to preserve/restore critical habitat and restrict stressors until the risk is eliminated. Assessing risk and developing a protection strategy is not possible without first establishing unit boundaries. Because the number of units that can be effectively managed is resource-limited (*6*), the delineation of units should be strategic and should prioritize evolutionary significance (*4*, *7*–*11*). Several criteria, such as genetic and ecological exchangeability (*10*), have been proposed for assessing evolutionary significance for CU delineation, but directly evaluating these criteria in natural populations is difficult (*5*).

Genetic methods play a pivotal role in the process of delineating CUs (*10*, *12*). To this end, genetic data from different regions of the genome are combined to produce measurements of overall genetic differentiation between populations. These measurements represent typical regions of the genome and serve as a proxy for evolutionary significance (*13*, *14*). However, because most genomic regions are primarily influenced by gene flow and genetic drift as opposed to selection, these measurements may fail to account for important adaptive differences between populations (*12*). Recent advances in genetic methodology facilitate the identification and evolutionary analysis of adaptively important loci (*15*–*22*) and provide an alternative way to assess evolutionary significance, but the utility of these loci for CU delineation is unclear and disputed (*12*, *23*–*27*).

Pacific salmon (*Oncorhynchus* spp.) provide a unique opportunity to investigate the application of genetic tools to the conservation of biodiversity below the species level (*4*, *6*, *28*–*30*). Despite extensive conservation efforts, Pacific salmon have been extirpated from almost 40% of their historical range in the contiguous United States, and many remaining populations have experienced marked declines and face increasing challenges from climate change (*31*–*35*). Reintroduction attempts of extirpated populations are largely unsuccessful because precise natal homing across highly heterogeneous environments has resulted in divergent selection and abundant local adaptation (*19*, *36*–*38*). Thus, maintaining existing stocks is critical for preserving the species themselves as well as the communities and ecosystems that rely on their presence (*39*). Genetic methods have been used extensively in delineating CUs in Pacific salmon [referred to as evolutionarily significant units (ESUs) or distinct population segments (DPSs) depending on the species] and, as a consequence of patterns of gene flow, have resulted in units that primarily reflect geography (*40*–*43*). Although current ESUs and DPSs certainly protect adaptive differences between distant populations, adaptations within highly connected populations are not necessarily protected (*10*, *34*). However, the evolutionary significance of these adaptations and the potential long-term consequences of not independently protecting them are poorly understood.

Perhaps the most recognized example of differential adaptation within highly connected populations of Pacific salmon is variation in adult migration timing (also called run timing) (*44*–*46*). In contrast

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to typical adult salmon that mature sexually before freshwater migration, premature migrating individuals have a complex behavioral and physiological adaptation that allows them to access distinct habitats, distributing ocean-derived nutrients higher into watersheds, and spawn earlier in the season (*46*). Because of their distinct migration time and high fat content (*47*), premature migrating populations also provide additional, more-coveted, and culturally important harvest opportunities (*48*). For example, indigenous peoples in the Klamath Basin in northern California celebrated the return of premature migrating salmon with ceremonies that progressed upriver with the salmon migration (*49*).

Premature migrating populations have suffered grossly disproportionate impacts from human actions, such as dam building, mining, and logging, because of their extended time in freshwater and reliance on headwater habitat (*14*, *34*, *40*, *42*, *46*, *50*, *51*). With few exceptions (for example, some interior Columbia Basin locations), genetic analyses find little differentiation between proximate premature and mature migrating populations (*13*, *52*–*59*), and as a result, they are generally grouped into the same ESU or DPS (*40*, *42*). Therefore, despite the extirpation or substantial decline of premature migrating populations, the ESUs or DPSs to which they belong usually retain relatively healthy mature migrating populations and thus have low extinction risk overall (*14*, *40*, *42*). Here, we investigate the genetic and evolutionary basis of premature migration to explore potential consequences of not independently protecting this beneficial adaptation as well as the utility of genomics for informing conservation.

RESULTS

Initial genomic analysis consistent with current steelhead DPS delineations

Dramatic examples of premature migration are observed in coastal (noninterior) populations of steelhead (anadromous rainbow trout; *Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*). In these populations, premature migrating individuals (called summer steelhead or spring Chinook) use receding spring flows during freshwater migration to reach upstream habitat before hostile summer conditions in the lower watershed, hold for several months in deep cool pools while their gametes mature, then spawn at similar times to mature migrating individuals that have just entered freshwater (*44*, *46*). We began our investigation by compiling a set of 148 steelhead samples from five coastal locations across four DPSs in California and Oregon (Fig. 1A). Four of the locations (Eel, New, Siletz, and North Umpqua) represent the few remaining watersheds with significant wild premature migrating populations. The fifth location, Scott, contains only mature migrating individuals. Our sampling focused as much as possible on individuals that could be confidently categorized as premature or mature migrating based on collection date and location (Fig. 1B and table S1).

To collect high-resolution genomic information from these samples, we prepared individually barcoded restriction site associated DNA (RAD) libraries, sequenced them using paired-end Illumina technology, and aligned the sequence reads to a recent draft of the rainbow trout genome (tables S1 and S2) (*60*). We then used a probabilistic framework to discover SNPs and genotype them in each individual (*61*). A total of 9,864,960 genomic positions were interrogated in at least 50% of individuals, and 615,958 SNPs (that is, segregating sites) were identified ($P < 10^{-6}$). Of these SNPs, 215,345 had one genotype posterior greater than 0.8 in at least 50% of individuals. Population structure characterization and genome-wide analyses in nonmodel organisms are typically carried out with far fewer SNPs (*62*). We conclude that the sequence data obtained are appropriate for genome-wide measurements and high-resolution analyses of specific genomic regions.

To characterize the genetic structure of these populations, we performed PCA and estimated pairwise F_{ST} using genome-wide genotype data (*63*). The first two PCs revealed four distinct groups corresponding to the four current DPSs (Fig. 1C). Siletz and North Umpqua, which are two different locations within the Oregon Coast DPS, did not break into distinct groups until PC6 (Fig. 1D), indicating relatively low genetic differentiation between distinct locations within a DPS. In all cases, individuals with different migration phenotypes from the same location were in the same group. The pairwise F_{ST} estimates also revealed strong genetic differentiation between locations but little differentiation between migration phenotypes from the same location (Fig. 1E). The mean pairwise F_{ST} between migration groups from the same location was 0.032 (range, 0.018 to 0.039; $n = 3$), whereas the mean between groups from different locations was 0.125 (range, 0.049 to 0.205; $n = 25$). The combination of this genetic structure and observations of hybridization between premature and mature migrating individuals (*53*) suggests higher rates of gene flow between different migration groups from the same location than between groups from different locations. Thus, as found in previous analyses, the overall genetic structure among steelhead populations is predominantly influenced by geography, as opposed to migration phenotype. We conclude that measurements of overall genetic differentiation from genome-wide SNP data are consistent with current steelhead DPS delineations.

Premature migrating steelhead explained by a single allelic evolutionary event at a single locus

To identify genomic loci associated with premature migration, we performed association mapping of migration category. We used a likelihood ratio test (*64*) with λ correction for population stratification (*65*) to compare 181,954 SNPs between migration categories in North Umpqua and found 14 SNPs that were significant (Bonferroni-corrected α level: $P < 0.05$). Strikingly, all of these SNPs were located within a 211,251–base pair (bp) region (568,978 to 780,229) on a single 1.95-Mb scaffold (Fig. 2A; fig. S1, A and B; and table S3). Furthermore, when this analysis was repeated with Eel individuals using 170,678 SNPs, we obtained a similar pattern of association (Fig. 2B; fig. S1, C and D; and table S3). The strongest associated SNPs in both sample locations were flanking two restriction sites approximately 50 kb apart and located just upstream and within a gene identified as *GREB1L* (Fig. 2C; see Discussion for more information on *GREB1L*). The strength of these associations was unexpected given the phenotypic complexity of premature migration and the relatively low number of samples analyzed. We conclude that the same single locus is strongly associated with migration phenotype in at least two DPSs.

To investigate the evolutionary history of this locus, we sequenced three amplicons, each of approximately 500 bp, from the *GREB1L* region in all individuals from all populations (Fig. 2C and tables S1, S4, and S5) and used these sequences to construct a haplotype tree based on parsimony (*66*). Strikingly, the tree contained two distinct monophyletic groups corresponding to migration phenotype (Fig. 2D). For 123 of 129 individuals, both haplotypes separated into the appropriate migration category clade. The remaining six individuals (four Siletz and two North Umpqua samples originally classified as mature migrating) had one haplotype in each migration category clade (Fig. 2D), suggesting heterozygosity at the causative polymorphism(s). Furthermore, although there was little differentiation within the mature migration clade, premature migration haplotypes from Siletz and North Umpqua were

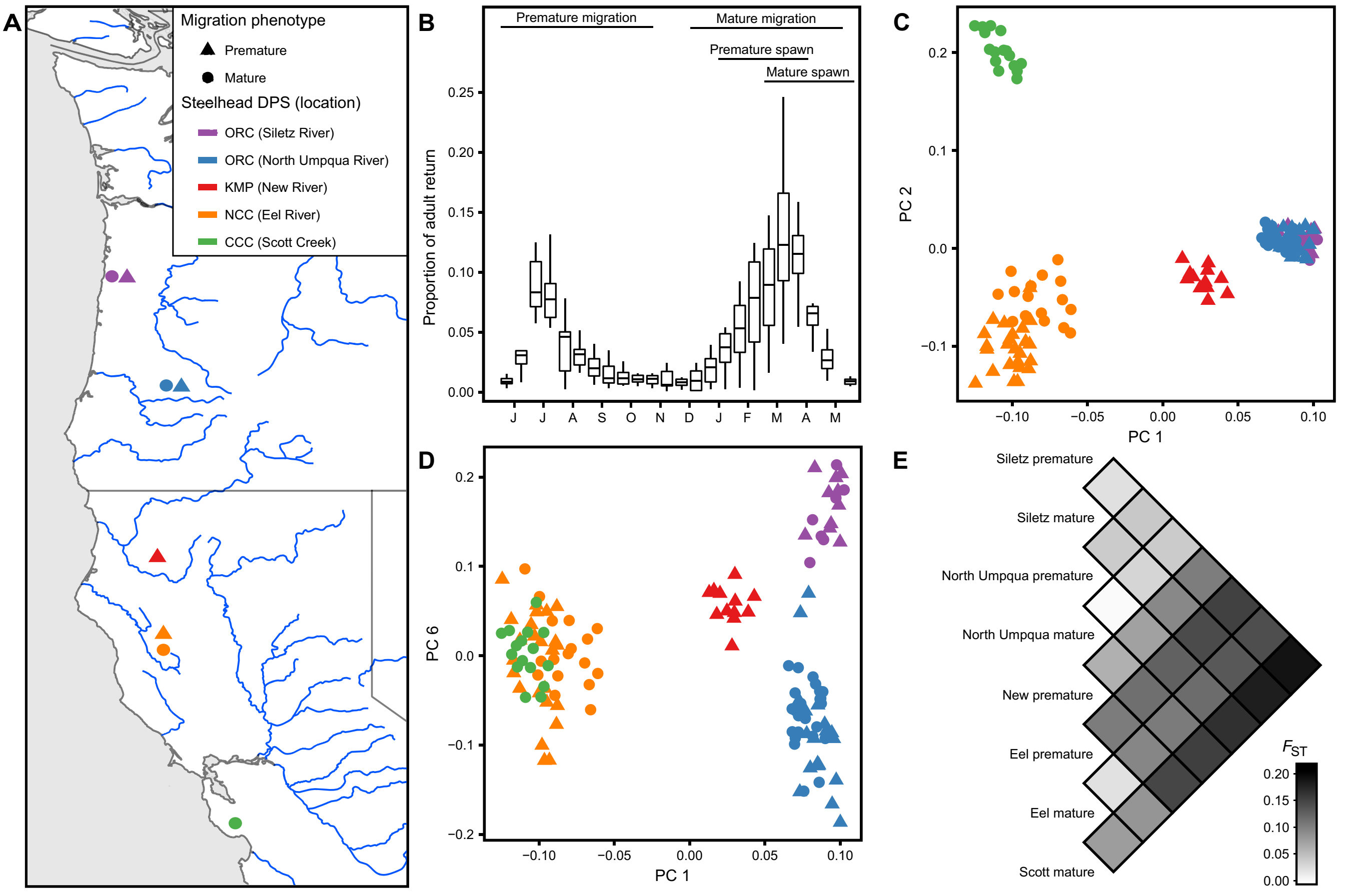

Fig. 1. Genetic structure of premature and mature migrating steelhead populations. (**A**) Map of steelhead sample locations and migration phenotypes; color indicates location, and shape indicates migration phenotype. (**B**) Bimonthly proportion of annual adult steelhead return over Winchester Dam on the North Umpqua River (2003 to 2013); horizontal bars depict migration and spawn timing of premature and mature migrating populations. (**C** and **D**) Principal component analysis (PCA) and (**E**) pairwise F_{ST} estimates using genome-wide single-nucleotide polymorphism (SNP) data.

more divergent from the mature migration clade than those from Eel and New (Fig. 2D; see Discussion for more information on heterozygotes and differentiation within the premature clade). The overall tree topology is inconsistent with premature migration alleles originating from independent evolutionary events in different locations because separate mutational events would be expected to occur on different haplotype backgrounds and result in premature migration alleles having a polyphyletic origin (*15*). We conclude that there is a nearly complete association between variation at this locus and migration category and that the premature migration alleles from all locations arose from a single evolutionary event.

To examine the evolutionary mechanisms leading to the dispersal of the premature migration allele as well as reconcile the difference between patterns of variation at the *GREB1L* locus and overall genetic structure, we summarized patterns of genetic variation using two estimators of θ (4*N*μ). One estimator is based on average pairwise differences (θ_π) (*67*), and the other is based on the number of segregating sites (θ_S) (*68*). When genome-wide data were used, both estimators produced similar θ values for each migration category (Fig. 2E). The *GREB1L* region of mature migrating individuals also produced θ values similar to the genome-wide analysis. However, premature migrating individuals from North Umpqua had strikingly lower θ values (Fig. 2E) and a significantly skewed site frequency spectrum (SFS) (Tajima's $D = -2.08$; $P = 0.001$) (*69*) indicative of strong, recent positive selection in the *GREB1L* region. Premature migrating individuals from Eel also had reduced θ values in the *GREB1L* region (premature: $\theta_\pi/\text{kb} = 2.48$, $\theta_S/\text{kb} = 2.67$; mature: $\theta_\pi/\text{kb} = 3.59$, $\theta_S/\text{kb} = 4.00$), but the SFS was not significantly skewed, consistent with an older selection event. Although both demography and selection can reduce nucleotide diversity and skew the SFS, this pattern is specific to the *GREB1L* region as opposed to genome-wide, implicating selection as the cause. Furthermore, the combination of a stronger signature of selection and a more divergent sequence pattern in the northern premature migration haplotypes is consistent with a northward movement of the premature migration allele. We conclude that, upon entering new locations via straying, positive selection allowed the premature migration allele to persist despite ongoing hybridization with local mature migrating populations.

Premature migrating Chinook also explained by a single allelic evolutionary event in GREB1L region

To broaden our investigation into premature migration, we compiled a set of 250 Chinook samples from nine locations across five ESUs in California, Oregon, and Washington (Fig. 3A). Similar to steelhead, our sampling focused as much as possible on individuals that could be confidently categorized as premature or mature migrating based on collection time and location (table S6). We then prepared individually

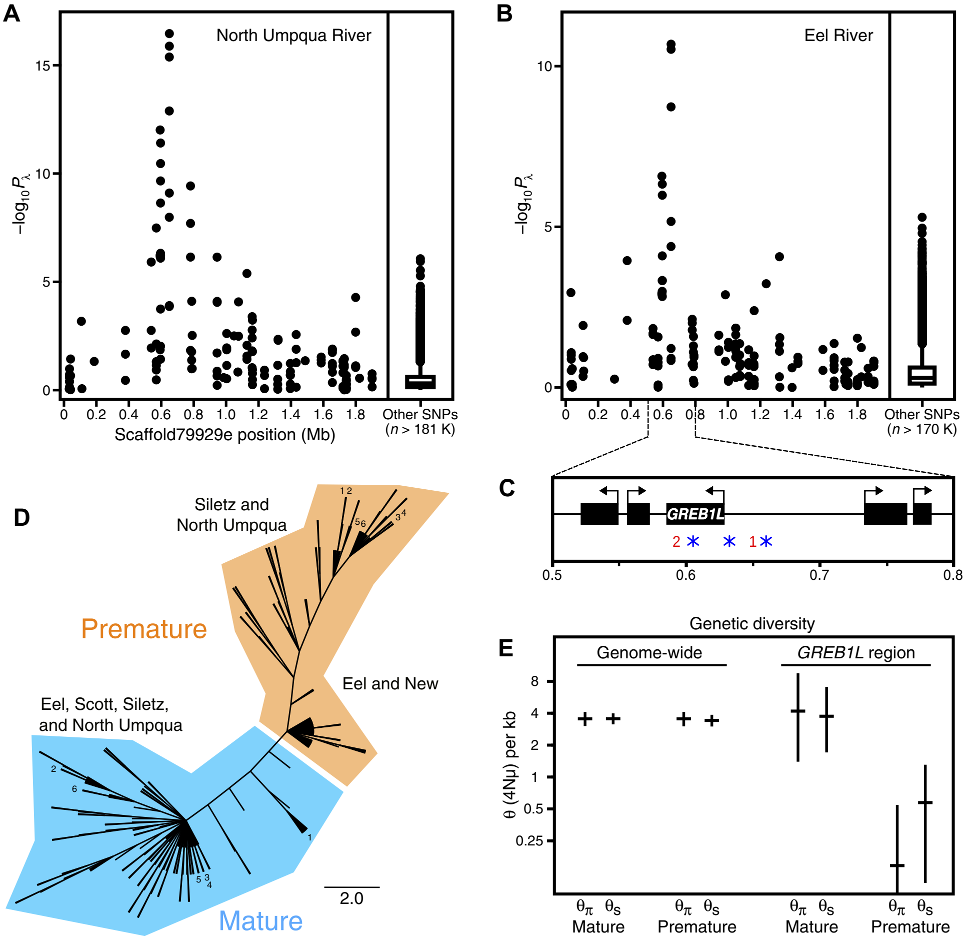

Fig. 2. Genetic and evolutionary basis of premature migration in steelhead. Association mapping of migration category in (**A**) North Umpqua River and (**B**) Eel River steelhead. (**C**) Gene annotation of region with strong association; red numbers indicate genomic positions of two restriction sites flanked by strongest associated SNPs, and blue asterisks indicate positions of amplicon sequencing. (**D**) Phylogenetic tree depicting maximum parsimony of phased amplicon sequences from all individuals; branch lengths, with the exception of terminal tips, reflect nucleotide differences between haplotypes; numbers identify individuals with one haplotype in each migration category clade. (**E**) Genome-wide and *GREB1L* region diversity estimates in North Umpqua for each migration category with 95% confidence intervals from coalescent simulations.

barcoded RAD libraries, sequenced them using paired-end Illumina technology, and aligned the sequence reads to the same rainbow trout reference assembly used above (tables S6 and S7). No reference genome is available for Chinook, and rainbow trout, which diverged from Chinook approximately 10 to 15 million years ago (*70*, *71*), is the closest relative with a draft genome assembly. With the methods described above, a total of 3,910,009 genomic positions were interrogated in at least 50% of individuals and 301,562 SNPs were identified ($P < 10^{-6}$). Of these SNPs, 55,797 had one genotype posterior greater than 0.8 in at least 50% of individuals. Although the alignment success was lower and subsequent SNP discovery and genotyping produced fewer SNPs compared to steelhead, the large number of SNPs discovered and genotyped should still be adequate for downstream analysis.

To characterize the genetic structure of these populations, we performed PCA and estimated pairwise F_{ST} using the genotype information described above. The first two PCs revealed four groups: the largest group contained all coastal ESUs, the second contained the two Puget Sound ESU locations, and the last two groups corresponded to the two locations within the Upper Klamath–Trinity Rivers ESU and were only differentiated by the second axis (Fig. 3B). In all cases, individuals from the same location but with different migration phenotypes were in the same group, and locations within groups became differentiated as additional PCs were examined. The mean pairwise F_{ST} between migration categories from the same location was 0.037 (range, 0.009 to 0.093; $n = 7$), and the mean between groups from different locations was 0.097 (range, 0.021 to 0.199; $n = 113$) (Fig. 3C). Thus, similar to what we found in steelhead, the overall genetic structure is strongly influenced by geography, as opposed to migration phenotype. We conclude that measurements of overall genetic differentiation from genome-wide SNP data are consistent with current Chinook ESUs.

To investigate the genetic architecture and evolutionary basis of premature migration in Chinook, we conducted association mapping with 114,036 SNPs using a generalized linear framework with covariate correction for population stratification (*65*, *72*). Strikingly, we again found a single significant peak of association (Bonferroni-corrected α level: $P < 0.05$) that contained five SNPs within 57,380 bp (537,741 to 595,121) in the same *GREB1L* region identified in steelhead (Fig. 3D and table S8). We next examined allele frequencies at these five SNPs and found a strong and consistent shift between all premature and mature migrating populations independent of location (Fig. 3E). Thus,

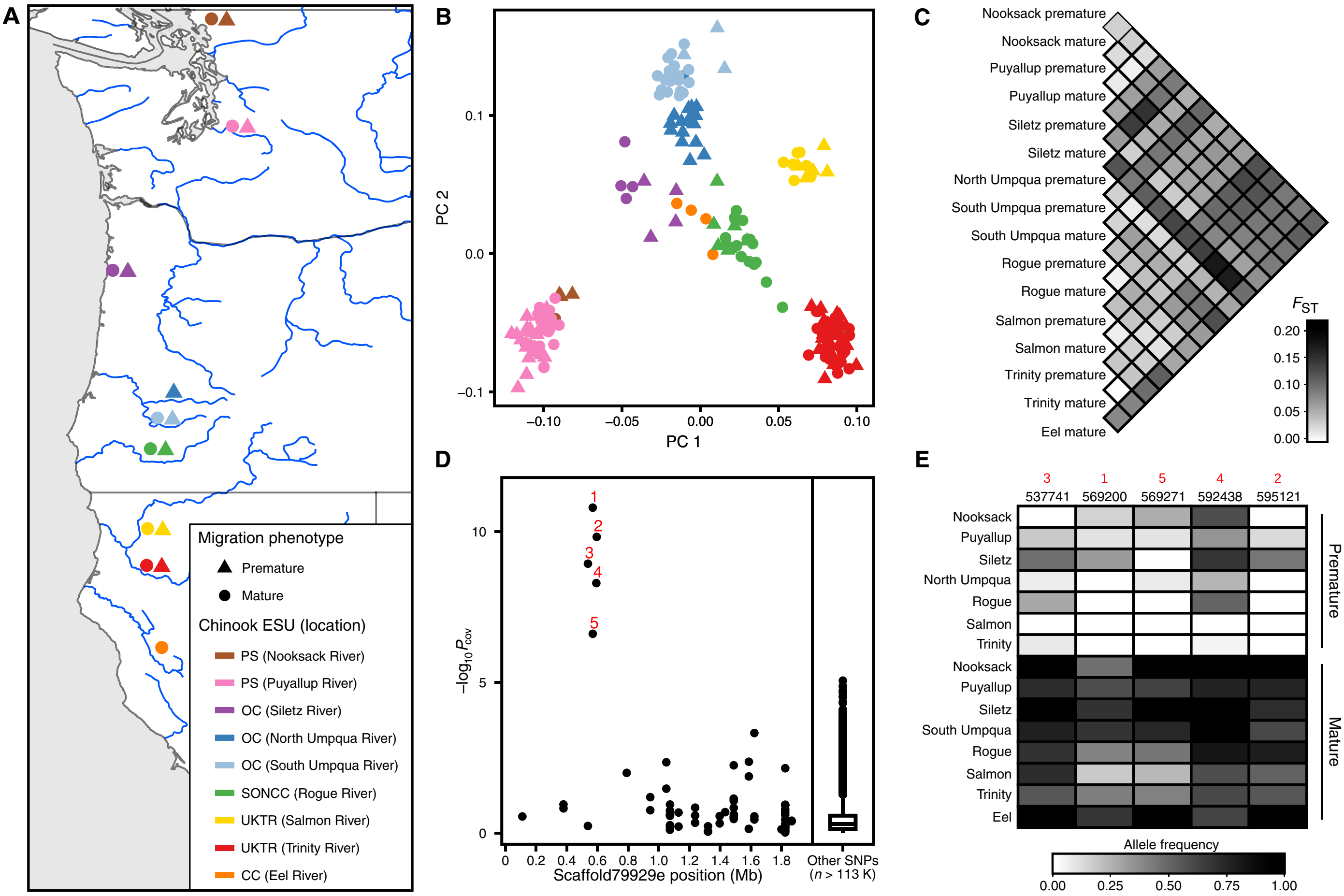

Fig. 3. Genetic and evolutionary basis of premature migration in Chinook. (**A**) Map of Chinook sample locations and migration phenotypes; color indicates location, and shape indicates migration category. (**B**) PCA and (**C**) pairwise F_{ST} estimates using genome-wide SNP data. (**D**) Association mapping of migration category in Chinook; red numbers indicate significant SNPs. (**E**) Allele frequency shift at significant SNPs between premature and mature migrating populations. Black numbers indicate SNP position on scaffold79929e.

despite having a lower genomic resolution and fewer samples per location, these results demonstrate that the *GREB1L* region is also the primary locus associated with premature migration in Chinook. Furthermore, the shift of allele frequencies in the same direction between premature and mature migrating populations across all locations is inconsistent with the premature migration alleles in Chinook being a product of multiple independent evolutionary events. Although the genomic region was consistent between species, the SNPs identified in Chinook were distinct from those in steelhead (tables S3 and S8). That is, the premature and mature migrating Chinook haplotypes are more similar to each other than to either of the steelhead haplotypes and vice versa, suggesting independent allelic evolutionary events in each species. We conclude that the same evolutionary mechanism used in steelhead, with a single allelic evolutionary event in the *GREB1L* region that subsequently spread to different locations, also explains premature migration in Chinook.

DISCUSSION

Our association analysis across multiple populations in each of two different species, as well as an independent analysis on Klickitat River steelhead (*73*), suggests that either the function or the regulation of *GREB1L* is modified in premature migrating individuals. Both *GREB1L* and its paralog *GREB1* are ubiquitous in and highly conserved across vertebrates. Although *GREB1* is known to encode a nuclear hormone receptor coactivator (*74*) and has been implicated in diverse biological processes (*75*–*80*), relatively little is known about *GREB1L*. However, a recent study found that *GREB1L* is differentially regulated by feeding and fasting in AgRP (agouti-related protein) neurons of the hypothalamic arcuate nucleus in mice (*81*). The strength of the associations, as well as the known role of AgRP neurons in modulating diverse behavior and metabolic processes such as foraging and fat storage (*81*, *82*), provides evidence for and an explanation of how the complex premature migration phenotype could be controlled by this single locus. An alternative explanation is that the *GREB1L* region only influences a subset of the phenotypic components of premature migration and that other important loci were not identified because of technical or biological reasons. Regardless, our results indicate that an appropriate genotype at this locus is necessary for successful premature migration.

Given that premature migration alleles at this locus are critical for premature migration, our results on the evolutionary history of these alleles provide important insights into the potential for premature migration to persist during declines and reemerge if lost. Finding that the same locus is associated with premature migration in both steelhead and Chinook indicates that genetic mechanisms capable of producing this phenotype are very limited. Although some loci can be predisposed to functionally equivalent mutations in relatively short evolutionary time scales (*83*, *84*), this does not appear to be the case with the *GREB1L* region. In predisposed loci, several independent mutations with the same phenotypic effect are observed in different populations of a single species (*83*, *84*). In contrast, our survey of many populations revealed only one evolutionary event that produced a premature migration allele in each species despite the 10 to 15 million years since they diverged (*70*, *71*). Regardless of whether or not additional allelic evolutionary events have occurred (for example, in the interior Columbia Basin), our finding that a broad array of populations shares alleles from a single evolutionary event suggests that mutational events that create new premature migration alleles are rare. Thus, if current premature migration alleles are lost, new premature migration alleles and the phenotype they promote cannot be expected to reevolve in time frames relevant to conservation planning (for example, tens to hundreds of years).

The rarity of mutational events that produce premature migration alleles at this locus highlights the importance of existing premature migration alleles. Unlike alleles with a small effect on phenotype, alleles with a large effect on phenotype are expected to be rapidly lost from a population when there is strong selection against the phenotype they promote (*85*). An important exception to this is when an allele is recessive and therefore masked in the heterozygous state (*15*, *85*). Thus, the inheritance pattern of the *GREB1L* locus has critical implications for the persistence of premature migration alleles during declines of the premature migration phenotype. Although our sampling focused on migration peaks (Fig. 1B) and was not designed to investigate the migration phenotype of heterozygotes, the recently published Klickitat data (*73*) included samples collected outside the migration peaks. Strikingly, a reanalysis of these data suggests that the same haplotype is associated with premature migration (Fig. 4A and table S3) and that heterozygotes display an intermediate phenotype (Fig. 4B and fig. S2). This explains the high frequency of heterozygotes in our Siletz mature migrating samples (4 of 10), which were collected before the peak of mature migration and far upstream in the watershed (table S1). Thus, the premature migration allele does not appear to be masked in the heterozygous state and cannot be expected to be maintained as standing variation in populations that lack the premature migration phenotype.

Two additional lines of evidence suggest that the premature migration allele will not be maintained as standing variation in mature migrating populations. First, the combination of the strong bimodal phenotypic distribution that is usually observed (for example, Fig. 1B) and the ecology of premature migration (see Introduction) (*44*, *46*) suggests a general pattern of disruptive selection against individuals with an intermediate phenotype (for example, heterozygotes). Although heterozygotes are expected to be produced by hybridization in locations where both migration categories exist (for example, we observed two heterozygotes in North Umpqua, which has the lowest genetic differentiation between migration groups; Fig. 1E), their presence does not suggest that the premature migration allele will be maintained by mature migrating populations. Second, the genetic differentiation between premature migration haplotypes from California and Oregon steelhead (Fig. 2D) indicates that, unlike mature migration alleles, premature migration alleles are not freely moving across this area. This result reveals that mature migrating populations do not act as an influential source or conduit of premature migration alleles despite being abundant and broadly distributed. Therefore, premature migrating populations appear ultimately necessary for both the maintenance and spread of these alleles.

Previously, studies revealing that overall genetic structure among populations of steelhead and Chinook primarily reflects geography (as opposed to migration phenotype) suggested that premature migration evolved independently in many locations within each species (*13*, *54*, *59*). This implied that premature migration is evolutionarily replaceable over time frames relevant to conservation planning (*13*) and is not an important component in the evolutionary legacy of the species (*14*). Although these interpretations were logical given the data available at that time, our results demonstrate that the evolution was not independent in each location but instead relied on preexisting genetic variation. Thus, although evolving the premature migration phenotype in new locations could be rapid if robust premature migrating populations are present in proximate locations, the widespread extirpation and decline of premature migrating populations (*14*, *34*, *40*, *42*, *46*, *50*, *51*) has greatly diminished the potential restoration and expansion (for example, into new habitats that become available with climate

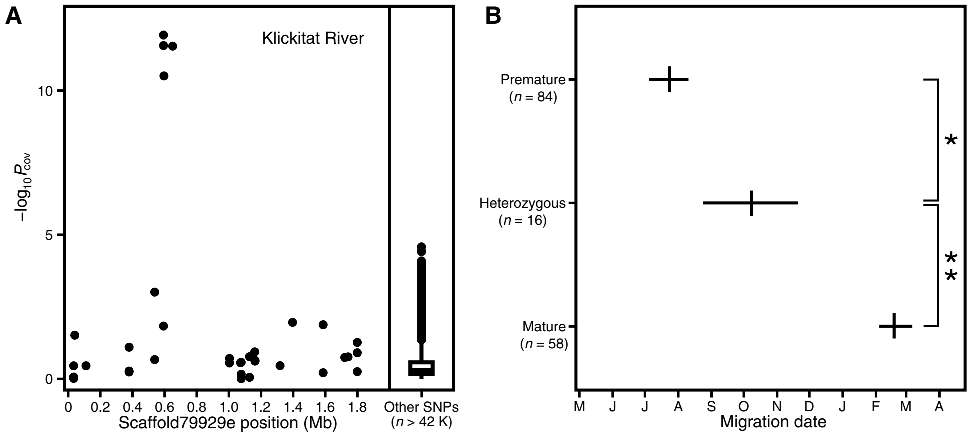

Fig. 4. Inheritance pattern of *GREB1L* locus. (**A**) Association mapping of migration date in Klickitat River steelhead. (**B**) Mean migration date and 95% confidence interval of the mean in Klickitat River steelhead categorized as homozygous for the premature migration allele, heterozygous, and homozygous mature. $*P = 0.00574$; $**P = 2.95 \times 10^{-5}$.

change) of premature migration across at least a substantial proportion of the range for both species (*19*).

Future work characterizing the distribution of premature migration alleles would improve our understanding of the extent to which the potential restoration and expansion of the premature migration phenotype has been diminished. For example, testing for the presence of premature migration alleles in locations where the phenotype has recently been extirpated would reveal how quickly these alleles are lost and potential restoration options. One possibility is that some heterozygotes still exist in these locations and could be used to restore the premature migration phenotype. The alternative is that the premature migration allele has already been lost and restoration of the phenotype would require introducing the allele from an outside population. Regardless, the results presented here will serve as a foundation for future work to determine optimal strategies for the conservation and restoration of premature migrating populations. Additionally, given the complex premature migration phenotype and evolutionary importance of premature migration alleles, future work that provides mechanistic insight into the *GREB1L* locus [for example, identifying the causative polymorphism(s) and characterizing expression profiles] could have important implications for areas ranging from conservation to biomedicine.

The combination of three key results from this study has broad conservation implications, which highlight the utility of genomics for informing conservation. First, we present an example of how a single allele at a single locus can have economic, ecological, and cultural importance. Second, we show that mutations producing an important allele can be very rare from an evolutionary perspective, suggesting that the allele will not readily reevolve if lost. Last, we observe that patterns of significant adaptive allelic variation can be completely opposite from patterns of overall genetic differentiation. Together, our results demonstrate that CUs reflecting overall genetic differentiation can fail to protect evolutionarily significant variation that has substantial ecological and societal benefits, and suggest that a supplemental framework for protecting specific adaptive variation will sometimes be necessary to prevent the loss of significant biodiversity and ecosystem services.

MATERIALS AND METHODS

Sample collection and molecular biology

Fin clips were taken from live adults or post-spawn carcasses (tables S1 and S6), dried on Whatman qualitative filter paper (grade 1), and stored at room temperature. DNA was extracted with either the DNeasy Blood and Tissue Kit (Qiagen) or a magnetic bead–based protocol (*22*) and quantified using Quant-iT PicoGreen dsDNA Reagent (Thermo Fisher Scientific) with an FLx800 Fluorescence Reader (BioTek Instruments).

SbfI RAD libraries were prepared with well and plate (when applicable) barcodes using either the traditional or new RAD protocol (*22*) and sequenced with paired-end 100-bp reads on an Illumina HiSeq 2500 (tables S2 and S7). In some cases, the same sample was included in multiple libraries to improve sequencing coverage.

For amplicon sequencing, genomic DNA extractions were rearrayed into 96-well plates and diluted 1:40 with low TE buffer (pH 8.0; 10 mM tris-HCl and 0.1 mM EDTA). Two microliters of this diluted sample was used as polymerase chain reaction (PCR) template for each of the three amplicons in the *GREB1L* region (Fig. 2 and table S4). Multiple forward primers were synthesized for each amplicon. Each forward primer contained a partial Illumina adapter sequence, a unique inline plate barcode, and the amplicon-specific sequence (tables S4 and S5). Initial PCRs were performed in 96-well plates using OneTaq DNA polymerase (New England Biolabs) at the recommended conditions with an annealing temperature of 61°C and 35 cycles. These reaction plates were then combined into a single plate that preserved the well locations. The pooled PCR products were cleaned with Ampure XP beads (Beckman Coulter), and a second round of PCR with eight cycles was performed to add the remaining Illumina adapter sequence and a unique TruSeq barcode to each well (tables S4 and S5). From each final PCR, 2 μl was removed, pooled, and purified with Ampure XP beads. The final amplicon library was sequenced with paired-end 300-bp reads on an Illumina MiSeq.

RAD analysis

RAD sequencing data were demultiplexed by requiring a perfect barcode and partial restriction site match (*22*). Sequences were aligned to a slightly modified version of a recent rainbow trout genome assembly (see scaffold79929e assembly and annotation) (*60*) using the backtrack algorithm of Burrows-Wheeler Aligner (BWA) (*86*) with default parameters. SAMtools (*87*) was used to sort, filter for proper pairs, remove PCR duplicates, and index binary alignment map (BAM) files (tables S2 and S7). In cases where the same sample was sequenced in multiple libraries, BAM files from the same sample were merged before indexing using SAMtools (tables S1, S2, S6, and S7).

Additional BAM file sets were generated to account for technical variation among samples. To minimize variation associated with the two distinct library preparation protocols used in Chinook (table S7) (*22*), we generated a set of single-end BAM files for Chinook that contained only trimmed reads from the restriction site end of the RAD fragments. To prepare these files, we trimmed these reads to 75 bp from the 3′ end after removing 5 bp from the 5′ end. Next, paired-end alignments were performed and processed as above. Last, reads from the variable end of RAD fragments were removed (table S7). To remove variation associated with variable sequencing depth, we generated a set of subsampled BAM files by using SAMtools to randomly sample approximately 120,000 alignments from paired-end BAM files for steelhead and approximately 60,000 alignments from single-end BAM files for Chinook. Subsampling to a lower number of alignments allows more individuals to be included in the analysis. We determined the optimal alignment numbers for subsampling by testing a variety of thresholds and determining the minimum before which the sample groupings started to become dispersed in PCA.

All RAD analyses were performed using Analysis of Next Generation Sequencing Data (ANGSD) (*61*) with a minimum mapping quality score (minMapQ) of 10, a minimum base quality score (minQ) of 20, and the SAMtools genotype likelihood model (GL 1) (*88*). Unless otherwise noted, samples with less alignments than required for subsampling were excluded (tables S1 and S6), and only sites represented in at least 50% of the included samples (minInd) were used.

PCA and association mapping were performed by identifying polymorphic sites (SNP_pval 1e-6), inferring major and minor alleles (doMajorMinor 1) (*72*), estimating allele frequencies (doMaf 2) (*64*), and retaining SNPs with a minor allele frequency of at least 0.05 (minMaf). For PCA, subsampled BAM files were used and genotype posterior probabilities were calculated with a uniform prior (doPost 2). The ngsCovar (*89*) function implemented in ngsTools (*63*) was used to calculate a covariance matrix from called genotypes. For association mapping, paired-end BAM files were used with two distinct tests. The frequency test with known major and minor alleles (doAsso 1) implements a likelihood ratio test using read counts (*64*). This test has good statistical power even with lower coverage data but does not allow the inclusion of covariates to correct for population stratification. The score test (doAsso 2) uses a generalized linear framework on posterior genotype probabilities (*72*). This test allows the inclusion of covariates to correct for population stratification but has less statistical power than the frequency test. For the Umpqua and Eel steelhead associations, the frequency test with λ correction for population stratification (*65*) was used because there were relatively few samples and a weak population structure. λ is the ratio of observed and expected median χ^2 values and used to correct the observed χ^2 values before converting them to *P* values (fig. S1, A and C, and table S3) (*65*). For the Chinook association, the score test with covariate correction for population stratification was used because there were many samples and a complex population structure (fig. S1E). The positions of each sample along the first 15 PCs were used as covariates.

Genome-wide F_{ST} between population pairs was estimated by first estimating an SFS for each population (doSaf) (*90*) using paired-end BAM files for steelhead and single-end BAM files for Chinook. Two-dimensional SFS and global F_{ST} (weighted) between each population pair were then estimated using realSFS (*61*).

To calculate Watterson's θ (*68*), Tajima's θ (*67*), and Tajima's *D* (*69*), we used SFS that were estimated as described above as priors (pest) with paired-end BAM files to calculate each statistic for each site (doThetas), which were averaged to obtain a single value for each statistic (*91*). The analysis was restricted to 565,000 to 785,000 bp of scaffold79929e for the *GREB1L* region analysis.

The coalescent simulation program ms (*92*) was used to determine 95% confidence intervals for the θ estimates from 10,000 simulations under a neutral demographic model. The input number of chromosomes was equal to the number of individuals used to calculate the θ statistics. For genome-wide confidence intervals, 100 independent loci and an input θ of 1, which is the approximate θ of a single RAD tag, were used. For the *GREB1L* region confidence intervals, a single locus and the empirical θ estimates were used. The significance of the empirical Tajima's *D* value was evaluated by generating a Tajima's *D* distribution from 10,000 ms simulations under a neutral demographic model. A single locus and the average between empirical values of Watterson's and Tajima's θ values in the *GREB1L* region were used. A Tajima's *D* distribution was also generated using the extremes of the θ confidence intervals, and the empirical value remained significant.

Allele frequencies were estimated (doMaf 1) (*64*) for the significant Chinook SNPs in each population that had at least four individuals with enough alignments for subsampling. Paired-end BAM files were used with the reference genome assembly as the prespecified major allele (doMajorMinor 4). Because some populations had low sample sizes, all samples were included regardless of alignment number.

Amplicon analysis

Amplicon sequence data were demultiplexed by requiring perfect barcode and primer matches. Sequences were aligned to the reference genome assembly described above using the BWA-SW algorithm (*93*) with default parameters, and SAMtools was used to sort, filter for proper pairs, and index BAM files (table S5).

Phylogenetic analysis was performed on samples in which two or more amplicons had at least 20 alignments (tables S1 and S5). Genotypes for all sites were called using ANGSD with the SAMtools genotype likelihood model, a uniform prior, and a posterior cutoff of 0.8. The genotype output file was parsed and converted into biallelic consensus sequences, with an IUPAC (International Union of Pure and Applied Chemistry) nucleotide code denoting heterozygous positions. These consensus sequences were input into fastPHASE (*94*) to produce 1000 output files that each contained two phased haplotype sequences per individual. Default parameters were used except that a distinct subpopulation label was specified for each of the five locations and base calls with a posterior of less than 0.8 were converted to Ns (unknown bases). Parsimony trees were then constructed from each fastPHASE output, and a consensus tree was called using PHYLIP (*66*).

In the initial phylogenetic analysis, one sample from the Eel River that was originally classified as premature migrating clustered in the mature migration clade (table S1). A PCA specific to the Eel River placed this sample at an intermediate position between mature migrating and premature migrating sample groups. Furthermore, this was the only Eel River sample that was homozygous for a haplotype on chromosome Omy05 associated with residency (*20*). Examination of the original sampling information revealed that this fish was much smaller than others and collected upstream from the main premature steelhead holding area (*56*), suggesting that it was a resident trout as opposed to an anadromous steelhead. Therefore, this sample was removed, and the analysis was rerun.

Scaffold79929e assembly and annotation

Our initial RAD analysis was aligned against a published reference genome assembly (*60*) and identified highly associated SNPs on three independent scaffolds. Given the state of the assembly, the sizes of the scaffolds with highly associated SNPs, and the positions of the highly associated SNPs on the scaffolds, we hypothesized that these scaffolds might be physically linked despite not being connected in the current assembly. We aligned four large-insert mate-pair libraries to the published assembly to look for linkages and estimate the distance between linked scaffolds (table S9). A perfect sequence match was required, and alignments to regions with high coverage were discarded. The resulting alignments from all libraries strongly supported a linear assembly with a total size of 1,949,089 bp that included the three associated scaffolds as well as four others (tables S9 and S10). This assembled scaffold was named scaffold79929e (e for extended) and added to the published assembly, and the seven independent scaffolds that composed it were removed to create the modified reference assembly used in this study.

Scaffold79929e was annotated with MAKER (*95*) using rainbow trout and Atlantic salmon (*Salmo salar*) EST (expressed sequence tag) sequences from the NCBI (National Center for Biotechnology Information) database, the UniProt/Swiss-Prot database for protein homology, a rainbow trout repeat library (*60*) for masking, AUGUSTUS (human) and SNAP (mamiso) gene predictors, a maximum intron size of 20,000 bp for evidence alignments, and otherwise default parameters.

Klickitat steelhead analysis

Single-end RAD data from 237 Klickitat River steelhead samples (*73*) were aligned to the modified rainbow trout genome as described above. SAMtools (*87*) was used to remove unaligned reads, sort, index, and randomly subsample BAM files to 500,000 reads to reduce the effect of PCR duplicates (*96*). All subsequent analyses were performed on subsampled BAM files using ANGSD (*61*).

Association mapping was performed using the score test (doAsso 2), with the migration date at Lyle Falls (May 1 set to day 1) (*73*) as a quantitative proxy for the premature migration phenotype (yQuant) because more direct measures (for example, gonadal maturation and body fat content at freshwater entry) were not available (this information is difficult to obtain and may require lethal sampling). The positions of each sample along the first nine PCs were used as covariates to correct for population stratification (fig. S1F). The PCA used to generate covariates was performed as described above.

Genotype data from the four associated SNPs were used to categorize individuals as homozygous for the mature migration allele, heterozygous, or homozygous premature. Genotypes were called (doGeno 4) with a uniform prior (doPost 2) and a posterior probability cutoff of 0.8 (postCutoff 0.8). Seven hundred fifty-one of 948 genotypes passed this cutoff. Two SNPs were flanking sites on the same RAD tag, had near-perfect consistency between genotype calls, and were treated as a single genotype for categorization. For an individual to be categorized as homozygous or heterozygous, all called genotypes were required to be in agreement and at least two of the three genotypes must have been called. A total of 158 samples passed these requirements, whereas 51 failed because less than two genotypes were called and 28 failed because of disagreement between called genotypes.

Migration date means were calculated with May 1 set to day 1 because it is an approximate date for the beginning of premature migration at Lyle Falls (*73*). Confidence intervals of the means were calculated by bootstrapping with 1000 replicates. The significance of differences in mean migration date between genotype categories was evaluated with Welch's *t* test. May 1 is somewhat arbitrary, and a subset of premature migrating individuals likely ascends Lyle Falls before this date (fig. S2). Furthermore, some individuals may enter freshwater then hold below Lyle Falls for an extended period before ascending to spawn. In either of these scenarios, individuals would be assigned a migration date indicative of mature migration, even though they were premature migrating. With the available information, we cannot be sure which individuals migrated under these scenarios. However, setting May 1 to day 1 is a conservative approach that, if anything, should underestimate the significance of the differences between mean migration dates for each genotype (Fig. 4B and fig. S2).

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/3/8/e1603198/DC1

fig. S1. Observed versus expected statistics for association mapping of migration phenotype.
fig. S2. Migration date distribution of Klickitat River steelhead at Lyle Falls with weekly binning.
table S1. Steelhead samples.
table S2. Steelhead RAD sequence.
table S3. Steelhead migration associated SNPs.
table S4. Steelhead amplicon primers.
table S5. Steelhead amplicon sequence.
table S6. Chinook samples.
table S7. Chinook RAD sequence.
table S8. Chinook migration associated SNPs.
table S9. Scaffold links.
table S10. Scaffold79929e assembly.

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The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation

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Karuk Cultural Impacts of Dam Removal

Prepared by the Karuk Tribe for use in the development of environmental reports associated with Dam Removal

Prepared by John Salter, Ph.D. and S. Craig Tucker, Ph.D.
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Revised 2010

Karuk History

The lands of the Karuk are characterized by the steeply folded and faulted mountains typical of the lower Klamath Basin. Mountains range in height from 600 – 7,500 feet in elevation and give rise to a dendritic pattern of streams that empty into the Klamath and Salmon Rivers. While relatively little archaeological work has taken place within Karuk Ancestral Territory, sites in nearby Lake County are dated in excess of 10,000 B.P. (Kaufman 1980; Meighan and Haynes 1970). The marked differentiation of Karuk language from affiliate languages of the Hokan linguistic stock is another indication of the time that the Karuk have lived as a people with a common language and cultural identity long removed from its place of origin. "The language is not closely or obviously related to any other; its presumed Hokan affiliations are distant. There was no known dialect differentiation" (Shipley in Sturtevant ed. 1978 p. 84). Based upon linguistic evidence, K.W. Whistler (1979) has hypothesized that the Northwest Coast region of California was first occupied by the Paleo-Indian ancestors of the Karuk. Whistler's reconstruction of a sequential inhabitation of aboriginal northern California places the ancestral Karuk as the first to arrive in the area, followed by the Wiyot around 1,100 B.P. Some 200 years later the Yurok, moved down through the Columbia River Plateau to settle in the coastal strip they continue to occupy.

With the absence of direct archaeological evidence, linguists are often called upon to provide a theoretical explanation for ancient patterns of human development. In this regard linguists have been an important source of hypotheses concerning the peopling of northwestern California as the rising waters of the Pacific Ocean have placed many of the early coastal sites as much as twenty miles out to sea at present times. The linguistic work of Bauman and Silver (1975) suggests that the Karuk and Wiyot had been direct neighbors prior to arrival of the Yurok and their settlement on the coast and lower stretches of the Klamath River in a pattern displacing the Wiyot. The Karuk, long in place from the lower Klamath Basin to the coast, reacted to the arrival of these new populations by largely abandoning the coastal strip as a base of occupation in favor of trading with the new populations. They also adopted the newly available technologies for fishing, preserving and storing fish and acorns which had been brought into the region by people whose lives had long depended on the use of salmon and acorns (Schalk 1977 and McDonald 1979).

It was in the Archaic Period that the ancestral Karuk first began to locate themselves more directly in relation to the Klamath River and its rich resources. While this early association was not of the intensity to develop in the later Pacific Period, it did mark a significant transition into the first adaptations of life to the riverene environment that characterize the ethnographic Karuk. Population densities remained relatively low but a broader range of resources were being more skillfully employed to gain greater control over the environment. Just as the migratory life of the Paleo-Indians was gradually superseded by the more broadly developed culture of the Archaic Period, the advances in cultural development of the Archaic Period were followed in turn by still greater cultural and social changes. It was in this period that the ancestral ethnographic Karuk developed the elaborate and sustainable life style based upon a large number of villages linked by ceremonies to one another, and to the down river tribes first encountered by Europeans in the early 1850s.

Cultural practices

Although the Karuk were characterized in the simplistic phrase by early ethnographers as a "salmon and acorn people," in fact they also continued to utilize the upland resources of the area for seasonal procurement of acorns, game, basketry materials, and other resources, as well as for religious purposes rather than for habitation (Kroeber 1925). Archaeological excavations of the interior area of northwestern California support this analysis of the Pacific Period ancestral Karuk living in permanent settled villages adjacent to the river while continuing to exploit high country resources. These studies indicate that although major village settlements were located along the river systems, there were also sites present on high ridges (H. Wylie 1976). Additionally, some 160 late prehistoric sites on the upper Klamath River within Karuk Ancestral Territory indicate that both site placement and population density were dependent on ease of fish procurement (Chartkoff & Chartkoff 1975).

The caches of smoked and sun-dried salmon and acorns of the Pacific Period allowed more than 100 ancestral Karuk villages to develop along the Klamath and Salmon Rivers. With a dependable source of food in place, a relatively dense population could now exist through the long hard winters of the lower Klamath without the necessity of a migratory life style. It was during the winters that stories were told while nets were woven and repaired, and tools and the celebrated ceremonial regalia of the area fabricated.

Villages

From antiquity reaching back immemorially to the Pacific Period, on one scale, and on another, to the time of the Ikxareeyavsa, the Immortals who prepared the way for the coming humans, the Karuk lived in fixed villages along the Klamath and a portion of the Salmon River. As with the downriver Hupa and Yurok who lived respectively along the banks of the Trinity and the joint Klamath Rivers, Karuk society was a long winding sequence of villages placed upon favorable beaches, bends, benches and fishing sites, centering life on the bounty, transportation and ceremony of the rivers. The Karuk lived in family houses and sweat lodges of hand split and adzed sugar pine or incense cedar planks.

The land above the river was utilized for hunting and gathering of foodstuffs and firewood. These seasonal hunting and gathering areas were visited and camped in for varying periods each year but the real villages were all found along the rivers which provided the thread joining villages and Indian peoples from the upper Klamath Basin to the Coast. The natural richness of this environment found expression in a wealth of ceremony, regalia and material goods without equal in California. The Karuk and the other Klamath and Trinity River tribes, the Yurok and Hupa, represent the southernmost expression of the great northwestern culture area stretching from the Klamath River to Alaska. For these tribes, the Klamath River was a highway connecting them as a cultural unit.

Although closely involved by marriage, ceremony and culture with other tribes of the area, the Karuk remained largely isolated from white contact prior to the arrival of miners, packers and tradesmen in 1850 and 1851 with the discovery of the Klamath goldfields. While villages were placed in advantageous locations on bluffs and bends of the Klamath River for the distance of Karuk territory, there were three zones of clustered villages that stood out and were each located at the mouth of sizeable watercourses entering the Klamath. These groups of villages were located, in order from downriver to upriver, at the mouths of Camp Creek (Tishaniik), the Salmon River (Mashuashav), and Clear Creek (Inam).

In 1852 whites burned the sacred villages of Yu’tim’iin and Ka’tim’iin (Downriver edge of Falls and Upriver Edge of Falls), near Ishi Pishi Falls, site of the annual World Renewal Ceremonies. Just below Yu’tim’iin and Ka’tim’iin lies Ike’s Falls, an area of intense rapids and holding places for migrating fish and a famous fishing station approximately one mile downstream of the mouth of the Salmon River. At this place, on the east side of the river was the village of As’anaamkarak. Across the river was Ameeky’aaoqam, a dance village and site of the First Salmon Ceremony. Just downriver from the mouth of the Salmon River was a small flat, Asapipmaam, the site of the Jump Dance. Just above the Salmon Rivers intersection with the much larger Klamath River and on the east side of the Klamath stands A’uuyich, or Sugarloaf, a pyramidal peak severed from a ridge by river action in past geologic ages, which stands as the center of the Karuk world together with the associated flat Ka’tim’iin ithivthan’een ‘aachip, the principal site of the Piky’avish or World Renewal Ceremonies, including the White Deer Skin Dance for which the Karuk are renowned. Across the river from Ka’tim’iin, at this most sacred of village clusters and ceremonial areas, is Ishipishrihak fatav’eenan known as Ishi Pishi (The End of the Trail), so named as it marks the point at the river that is the end of the Medicine Man’s (Fatav’eenan’s) trail.

Upstream from Ka’tim’iin some 20 miles and at the mouth of Clear Creek is Inaam, site of the first enactment of the annual World Renewal Dances. Some eight miles down the Klamath from the mouth of the Salmon lay Pan’amniik, another ceremonial village that became the location of the town of Orleans. In the two decades following first contact with Europeans, the easily accessible placer gold was mined away, and as mining became an enterprise requiring capitol and massive mining equipment, miners declined in numbers and Karuk people returned to their ancestral territory, sometimes resettling in their old village sites despite these villages having been burned and ransacked repeatedly. The favorable locations of Karuk villages at these places made them equally desirable for the Whites who had come to the area and what had been Karuk villages became the towns of Orleans, Somes Bar and Happy Camp.

Karuk villages were also located along the Salmon River, the largest of the Klamath tributaries within Ancestral Territory. The Karuk maintained villages for roughly half the distance from the mouth of the Salmon near Ka’tim’iin to Forks of Salmon (Samnaanak), some 15 miles upstream that was home to the Shastan Konomihu.

Culture

It is from the rivers in their aboriginal wildness, that the core cultures of northwestern California, those of the Yurok, Hupa and Karuk, developed their elaborate and specialized expressions. The relative plenitude of resources in this area was husbanded by long developed strategies of land management, largely through the use of low intensity fires. This use of fire existed within a rich and elaborate ceremonial expression of respect and responsibility to the natural environment and its spiritual expressions.

The material culture of the core cultures of the lower Klamath tribes, including the Karuk, was observed by Kroeber, as being undistinguished from other California Native cultures in their range of inventions, but excelling in craftsmanship and decorative qualities. Kroeber refers to this as difference as “deep seated and …manifest at almost every point” (Kroeber 1925, p. 1-2). He goes on to list a range of material objects including slab houses, canoes, mauls, pipes, acorn stirrers, netting shuttles, spoons and obsidian blades which the core cultures shared with other California Native cultures, but which in the core area demonstrated “a different attitude, an appreciation of values which in the ruder central and southern tracts is disregarded” (Ibid.). Outside the core area, objects were likely to be made of relatively easily shaped wood, and would remain unadorned with decorative elaborations such as carved or incised motifs. Within the core area, the same object was likely to be fabricated of a more demanding raw material such as antler or stone, and decorated with a level of interest not generally present in the remainder of California.

The same process of elaborated decoration and heightened interest, which holds for cultural objects, was also true for money. Money was known and prized throughout aboriginal California, but it was in the core culture area of Northwestern California that the influence of money and the elaboration of prices, fees and fines reached a peak. While tribes from every portion of California were aware of and made use of the institutions of blood money, bride price, and monetary compensation to mourners prior to holding a ceremony, it was only in the core area that “every injury, each privilege or wrong or trespass is calculated and compensated” and “His law is of the utmost refinement. A few simple and basic principles are projected into the most intricate subtleties; and there is no contingency which they do not cover” (Ibid. pp. 2-3).

At the same time the Karuk and other core area cultures so clearly represent a larger northwest cultural influence, they lack even the rudiments of the elaborate social organization or political units characteristic of northwestern tribes such as the Kwakiutl or Haida. They were entirely individualistic with regard to society. There are no “clans, exogamic groups, chiefs or governors” (Ibid. p.3).

Values

Although Kroeber visited the Karuk periodically beginning in 1900, the same remoteness that left the Karuk relatively less impacted by the invasion of Europeans than their downriver neighbors the Hupa and Yurok, left them relatively unstudied by the ethnographers of the late nineteenth and early twentieth centuries. Unlike their larger downriver neighbor, the Yurok, whose territory included the highly desirable coastal zone, and unlike the Hupa, the Karuk never had a reservation established. Although there were military efforts to force the Karuk onto the Hupa reservation, the attempts were eventually abandoned and following the extensive destruction of their villages in the early years of the gold rush, the Karuk began returning to the sites of their former communities.

Writing in 1877, Powers referred to the Karuk as “probably the finest tribe in California.” Speaking to Karuk character and personality, he observed the Karuk to be “brave when need is, extremely curious, inquisitive and quick to imitate… and merry with his peers.” (1877:21) Beginning some four decades later, A.L. Kroeber wrote extensively on the relatively accessible Yurok with which he tended to merge the Karuk culture, considering the two as “indistinguishable in appearance and customs, except for certain minutiae” (Kroeber 1925:98)

Environmental Relations

Over an uninterrupted period of thousands of years, the Karuk people developed land management to a fine science. The conjunction of ritual, spiritual and technical elements for the management of sustained vigorous ecosystems resulted in a system of land management and cultural perspectives among the Karuk and the neighboring tribes which not only were not destructive of the natural systems within which they lived, but which in fact served consciously to enhance and enrich the diversity of these systems. These strategies of management were maintained from the grass roots level, not by a powerful command structure imposing its will on the land.

Fishing

Kroeber and Barrett discuss the Karuk as one of a number of “core tribes” dependent upon fish within a social system of enforced rights:

> The best fishing places along the rivers were privately owned, sometimes by single individuals, sometimes jointly by several. In the latter case, a fishing place could be used by each owner in rotation, according to the proportionate share of his ownership. An owner might give someone else permission to fish there on the day or days when his turn would normally come. But no one was permitted to fish or to establish a new fishing place immediately downstream from a recognized fishing place…most inferior fishing places, and a few excellent ones were not privately owned but were open or public… (Kroeber and Barrett 1960 p. 3)

The concept of ownership applied strictly to the right to fish and not to ownership of land along the river. Gifford (F.N. 1939 p. 42) gives the example of a half mile stretch of river named Pawat and Jsununam (Where they start fishing for Chinook salmon) about which a Karuk informant stated “emphatically” that the issue was not who owned the land within which a fishing area lay, but that ownership related strictly to the right to fish. Those possessing what are still referred to as “rights” had, as was characteristic of the Karuk, degrees of flexibility in this ownership of rights. The owner of rights at a particular fishery might sell those rights in all or in part; might give away surplus fish and might allow others to fish at the site of his ownership. The concept of rights was not restricted to fishing sites but extended as well to acorn-gathering and hunting rights specific to certain areas. These rights, which had the force of law, might be attained by inheritance, as a gift or as payment for services. Women could own rights while not fishing themselves, but being fished for by a man, usually a relative.

Species of Fish Utilized Within Aboriginal Karuk Territory

The Klamath River provides a spawning area for several species of fish that were and continue to be utilized by the Karuk. These fish represent simultaneously a major food resource, the focus of ceremonies and more recently an issue of cultural sovereignty and survival.

Karuk list the principal Klamath River fish as follows:

1. Chinook or King Salmon: The spring run entered the river in March and were called ishyaat, but might not be eaten until after the ceremony made for them at Ameeyky’aaraam. This was the species for which lifting-net scaffolds were set up, though in creeks it was harpooned.

   Fall run Chinook who entered the system in late summer were referred to as áama. Historically, a very late fall run of Chinook entered the system. The males of this run had a pronounced hook shaped nose and were call páwat.

   Karuks also held in high regard the chiîpich. This fish is described by elders as a silvery Chinook of uniform size approximately 10 inches in length. Chiîpich are an out-migrating smolt that reared in the productive waters of the Upper Basin, the chiîpich gathered in refugial deep water pools near Inaam. During Pikyawish, the Fataveena or medicine man still hikes to a prayer seat overlooking these pools and prays for the chiîpich.

   2. Coho or silver salmon (also sometimes locally called dog salmon): (achvuun or ichwon). It was very red-fleshed, rather dry, not fat. The run began in October.

   3. Steelhead: (s’aap). In winter, at high water, they continued to be taken with platform lifting nets after the salmon completed their runs.

   4. Trout: (ashkup or askuup), were in the river and creeks the year round.

   5. Sucker fish: (chamuxit or chamuxich). Bony, not considered too desirable, but available the year round.

   6. Bullheads: (xa’nkiit), bullheads are a creature of significance in Karuk creation stories, now called “marbled skulpin.”

7. Sturgeon: (ishrixihara or ishx'ikkihar) Occurs upstream only to Ishi Pishi Falls which it cannot hurdle.

8. Pacific Lamprey, (akraah) – Referred to locally as eels, lamprey enter the system in December arrive in Orleans in April. A second run enters the system in February and arrives in Karuk territory in June. Lamprey are still harvested by the Karuk using several traditional methods such as baskets submerged in the river, hooks mounted on canes, trigger nets, or by hand using eel fern as a glove.

Salmon and Trout

There are five scientifically recognized species of Pacific Salmon, Oncorhynchus. Of these the King or Chinook, O. tschawystcha, and Coho or silver, O. kisutch are most frequently found in the Klamath. The other three species, the red or sockeye, O. nerka, the humpback, O. gorbuscha, and the chum or dog salmon, O. keta, are occasional strays into the Klamath system. It should be noted that recent genetic studies confirm the Karuk assertion that spring-run Chinook are a different species than fall-run Chinook.

Unlike the salmon of the Klamath River, steelhead are an anadromous species of trout, which do not die upon returning from their life as mature fish in the Pacific to spawn in the Klamath. The Klamath steelhead are the rainbow trout, Salmo gairdnerii ssp. irideus. In aboriginal times and prior to construction of dams, including Iron Gate Dam, the relicensing of which is the reason for this study, these species spawned freely not only in the Klamath and its tributaries, but in Klamath Lake and well beyond. Steelhead appear in the Klamath River in three runs.

The Karuk and other tribes of the core region recognize two runs of Chinook, or King, Salmon. Spring Chinook salmon are the subjects of the First Salmon Ceremony, performed in coordination between the Yurok and Karuk. This fish, whose importance has raised it to the totemic level, historically spawned as far north as the Williamson River. This portion of the drainage was available as spawning grounds prior to the damming of the Klamath River and the reconstruction of Klamath Lake in its present form. This First Salmon Ceremony was conducted around April when the fish first breeched the sandbar at the mouth of the Klamath, marking their transition from the Pacific Ocean back to the fresh water of the Klamath River. As these “springers” make their way up river, the Karuk mark their arrival at Ameeky'aaoqam, below the mouth of the Salmon River. The spring salmon were followed by the fall Chinook salmon.

Literature as well as oral tradition indicates that prior to an extended series of impacts on the fishery, beginning with the miners, salmon were entering the river in species distinguishable pulses throughout the year. The pulses which constitute runs mount and then decline with the progress of the run. The major run was that of the spring salmon. Snyder quotes from G.R. Field:

> As the run of winter steelheads ceases, about March 30, spring Salmon begin to come. A few enter the Klamath in the later part of February, but the run really starts in March and slackens or almost entirely passes by the last of May. These fish average about 11 pounds in weight and are indistinguishable from those which come later, except that the eggs are always immature. These spring salmon may be caught in the smaller streams fed by melting snow at the headwaters of Salmon River during the month of May (Snyder, p.19).

Spring salmon are said to have "lingered" in the vicinity of spawning beds until they mature and then spawn with the fish of later runs. They were also known as "silvers" due to their bright colors that gradually become indistinguishable from the coloration of other migrations in the period prior to spawning, having matured in the vicinity of the spawning beds. By the time of Snyder's writing in 1931, the spring run had declined from being the major run to the point that he characterizes it as being of "relatively little economic importance" (Ibid.).

Writing with a historical perspective of changing runs, Snyder makes the following observation concerning the migratory patterns of the fall salmon in 1931:

> The summer migration of king salmon up the Klamath River begins about the first of July, mounts rapidly by the last of the month, reaches its maximum in August, declines gradually in September, and falls away almost entirely before the beginning of winter. There is no definite break between the spring and summer migrations, and it seems also that the fish in small numbers continue to appear through November and even later. A spawning migration of steelheads comes with that of the king salmon. And a run of silver salmon Starts early in September and continues through October and November. The spring migration has now lost its economic importance and seems to have almost entirely disappeared. It was formerly connected at its waning period with the summer run. The fish of the spring run enter the river during its flood height of very cold water, and pass up stream under the same conditions, while the summer migration starts as the winter and spring floods subside, most of its fishes passing upstream during a minimum flow of water…(Snyder, p.23).

In should be noted that Snyder's comments come thirteen years after the completion of Copco Dam.

In the ethnographic interviews to follow references are made to this pattern of loss of runs which were once of great vitality and supplied fish at times of the year when runs are no longer taking place.

Sturgeon and Eel

Two species of that ancient fish the sturgeon, the white sturgeon, Acipenser transmontanus, and the smaller and less numerous green sturgeon, A.medirostriu (acutirostris) are anadromous species which migrate as far up river as Ishi Pishi Falls on the main-stem Klamath. Sturgeon also utilize habitat in the Salmon River as far up stream as Oak Bottom.

The Pacific lamprey eel, Entosphenus tridentatus, is highly prized as a food source and like the salmon ascended to Klamath Lake as well as numerous tributaries in their spawning migrations.

Karuk ancestral territory is also home to two species of freshwater, non-anadromous sucker, the Klamath coarse-scale sucker, Catostomus snyderi, and the Klamath fine-scale sucker, C. rimiculis.

Fishing Methods

The several species of fish utilized by the Karuk were taken by a variety of methods depending on the section of river or stream, the nature of the flow and the species of fish. Hewes (1942 pp.97-98) list includes: single and double-pronged toggle harpoon, gorge hook, double-pointed angle hooks, V-frame dip net (large), multipronged spear, gaffs, basketry traps, fish dams, and hoop nets.

Weirs (ithg'aah)

According to Mary Ike, the Karuk built weirs at the following six locations over a distance of 25 miles of river, with only one weir being constructed per year, an indication of the labor-intensive nature of the undertaking (Gifford, F.N. 1939-42; names added by Kroeber, 1936). These locations, in descending order on the Klamath River, were as follows:

> Above the mouth of Irving Creek "below the Sancho mine." (The Irving school is between 9 and 10 mi. upriver from the mouth of the Salmon.)
> On lower Salmon River, below the [old] bridge at Somes Bar. (Probably Shakirpak (sak'iripirak) or Shihtira (sihf'irih), a fraction of a mile from the Klamath.)
>
> At Oak Bottom Flat. (This is Vunharuk (vunx'arak), something over a mile above Somes Bar, about two and a half miles up from the mouth of the Salmon, and about a mile below where Wooley Cr. Flows into it.)
> Back on the Klamath, at Orleans (Pan'amniik) something over seven miles below the mouth of the Salmon.
>
> At Tuyuvuk (tu'uyvuk), Ullathorn Creek and Bar (not quite 3 mi. below Orleans).

> At Wupam (v’uppam), (Red Cap, about 4 mi. below the last; it was the most downriver of Karuk towns).

Georgia Orcutt named an additional three Karuk weirs.

> Aft ram (aff’aran), at Stanshaw Creek.
> Afsuf (afchuf’ichthuuf), the creek next below Camp Creek, on the same side.
> At Forks of Salmon (exact location uncertain).

This last named weir at Forks of Salmon is of particular interest as it indicates the close level of cooperation, and something of the relationship between the Karuk and the Konimihu of the Forks of Salmon area. Kroeber and Barrett discount the reference to a weir located at Forks of Salmon as “a loose statement,” indicating a location “somewhere up the Salmon,” or as a misstatement pertaining only to the post-contact period. This was a time following the virtual extinction of the relatively helpless Konomihu in which the Karuk indisputably began inhabiting the Salmon River well up the South Fork of the Salmon River past Forks of Salmon. In fact, according to oral tradition of the Karuk, there was a longstanding relationship between the Konomihu and the Karuk. The Konomihu, lacking the numbers to construct a weir on their own, as they lacked the wealth to hold their own ceremonial dances, relied on a close level of cooperation with the more numerous Karuk people. The Konomihu and the Karuk were also allied in the defense of the Konomihu against incursion by both the Hupa and the New River. This relationship indicates that Karuk interests did not end with the last Karuk village upriver from the mouth of the Salmon River.

The ceremonial significance of two weirs may be gauged by the coordination between their construction and accompanying ceremonies. The weir at Afsuf (afchuf’ichthuuf) was built following the Jump Dance at Amekiarum (ameeky’aaraam) in July. At this time the Fatawanun spend four days fasting and praying in the sweathouse at Paniminik (Pan’amniik). Similarly, construction of the weir at Wupam (V’uppam) (Red Cap) was attended by the Fatawanun (Fatav’eenan) spending five days in the sweathouse (Kroeber and Barrett p. 20). Construction of the other weirs was unaccompanied by ceremonies, although a girl’s puberty dance, the Flower Dance (‘ihuk), was customarily held following construction of the remaining weirs.

According to Karuk accounts, weirs were created by one of the immortals (Ikhareya) as an aspect of creating salmon and preparing the structures and techniques that the humans to come would use in their capture:

> When he had made the salmon, this ikhareya (ixxare’eyavsa) made what the Indians use: he made the scaffolding to fish from. He made it of long poles. He bruised grapevines with which to tie the poles and made it all good. He thought, “This they will do when they fish.” He laid a plank on the poles to fish from, and on this he put a little stool so that they could sit while they fished. He thought he had made everything. Then after a time he thought, “It is not quite right as I have made it.” He put a screen of brush at his fishing

> place. He concluded, “It is not right like that. It is too far out in the stream. Let it move back a little toward the shore.” Then he thought, “It is not right yet. I do not think it will be good if I use brush. I do not want the salmon to go through: I want them to go right where I am fishing with the net. Let me make something flat and even.” So he made a weir (ithy’aah) (”dam”) of sticks and tied them together with pounded twigs (into a mat). Then he thought, “Now I think it is good as I have made it. Now when the people grow they will do that. It is a good way I have made it now.” So now the people do like that. When they grew they saw what he had made (“Karuk Myths,” Kroeber 1980 pp 71-72.)

Karuk weirs took around two weeks to construct, including preparation of the poles and logs. Once in place, the weir was left until removed by high water. Weirs offered the advantage of allowing a winter’s supply of salmon to be caught for many families. During their period of use men were engaged in fishing and women would prepare and dry fish for storage.

Fish Nets

The aboriginal Karuk utilized both large lifting nets requiring platforms and a trigger string called uripi, or in its larger form, amvauripa, which could be up to twelve feet, (Hewes F.N. 1940).

The dip net or plunge net (t’akkirar) is still in use. This form of net is used at the only authorized fishing site reserved for aboriginal Karuk fishing at Ishi Pishi Falls. The net is utilized from a shelf of shoreward rocks or boulders and is plunged into pools just below the falls where salmon rest prior to making their way up the falls. Both types of nets were woven of fibers extracted from the leaf of the native iris, Iris macrosiphon (apkas). Characteristic of the Karuk, this process involved a gender-based division of labor with women extracting the two fibers found in each leaf using a muscle shell fitted into a leather holder and set on the processors thumb. In turn, men twisted the fibers into cordage, which was then woven into nets.

Basketry Traps

One technique of fishing high-water creeks in winter utilized trough-shaped basketry traps called pisimvaru, referring to the bent up sides. Larger traps were constructed of split spruce poles “each six or seven feet long and set several inches apart” (Ibid.). With widely spaced longitudinal poles these traps captured only the larger species, salmon and steelhead, while smaller, similarly constructed traps were used to take smaller fish such as suckers and trout. These traps were laid open end downstream in line with the water flow so that fish swimming upstream passed unimpeded into the trap from which they could not escape and were removed once a day with the trap being left in place. In style, this fish trap resembles a Karuk bird trap, which the prey enters unimpeded but finds no exit. Hewes also reports that ordinary burden baskets were sometimes called upon as scooping fish traps. Driver includes in the list of Karuk fish traps “a half-cylinder type of trap and…another…pointed at both ends…. (Driver (1939, pp.313, 379).

Pacific Lamprey (eels) (akraah) continue to be valued as a rich source of fat and are taken by a variety of techniques including small-meshed nets, gaffs, baskets and by hand, now utilizing a glove for a better grip, as the eel work their way over rocks at night in their upriver migration. The eel trap or basket is made of an open weave basketry anchored in place by rocks as well as line. This trap takes advantage of the eel’s tendency to move at night and hide by day in gravel.

Fish Harpoons, Other Devices and Methods

Harpoons are distinguished from spears by the presence of a detachable head fixed to a foreshaft or directly to a mainshaft. The head is attached to the foreshaft or mainshaft by a toggle line that held the speared fish and acted as means of cushioning the shock of a fighting fish, much like the springiness of a modern fishing rod allows fish to be played without tearing out the hook. Harpoon styles consisted of both double and single toggle points.

In one of a series of creation stories that present logical accounts of the origin of humans, institutions and tools, Chukchuk,(ch’uukchuuk) Osprey or Fish Hawk considered needs and developed solutions, a very Karuk process. In this series of origin accounts, Chukchuk (ch’uukchuuk) develops the two-pointed harpoon as a means for those to fish who did not own rights to one of those previously referred to sites at which large numbers of fish were to be caught by a variety of net techniques.

> He took a long stick. At the end of it he fastened two small ones. He thought, “I will spear salmon. Let me make that kind. Let me make it so that if a man has no fishing place and he sees salmon he can catch them. If he has no net he will kill them in this way.” So now if people own no fishing place they spear salmon. Chukchuk was the one who made it thus (Kroeber, 1980 p. 72).

Due to the efficiency of nets and weirs in the harvesting of large numbers of salmon, and the flexibility of fishing rights which provided for gifting distribution as well as allowing those with no “rights” to fish, the harpoon was utilized as a secondary harvest technique and was used in the capture of steelhead in their spring spawning runs up streams too small to allow netting as a strategy (Hewes, F.N. 1940). Similarly, fish were sometimes taken with bow and arrow (Driver 1939: pp. 313, 379). Hewes (F.N., 1940) reported that Karuk sometimes took sturgeon by means of a twisted grapevine noose slipped over the fish’s tail which was then tied to a tree as these giant (eight to nine feet long, 200 pound plus) fish were too strong to be held even by more than one man.

Current Fishing Issues

The following statement by a lifelong traditional Karuk fisherman indicates something is the range of difficulties brought the modern fishing practices by the presence of the dams and their effect on the Klamath River.

> 1966 was the first year I fished but I was down there from 1957 on when I was six years old, clubbing and helping pack fish and cleaning, I did everything for the fisherman. I packed their poles for them. It was all part of learning to be a fisherman. We would talk about the fish and how they come in and how you hit the holes for them and how to hang on to them because anybody could probably tell you it's not that easy, you don't just pull them out. There used to be a lot more water, deeper holes, better places pin to them. You used to twist your poles in the holes so you had to have pretty big poles on your net. In those days they built pretty strong heavy poles, heavy. You would twist them so that would get your fish in the net. When the water got lower you couldn't really do that. You had to pull them out and twist them when you are on top of the water because you don't really have the depth of water.
>
> When I started fishing you could fish all summer. They would start running in the middle of August and then go all the way to the winter. They would turn black in November. We liked fishing so much that sometimes we would be down there catching those black fish with white meat. At that time there were different types of salmon. There were different runs, I don't even recall the names of them. I know they had Indian names, they weren't all Chinook and Cohos like now. Now they are mostly all hatchery fish. The biggest effect of the dams from my perspective is cutting off all that other water, the headwater, all that spawning habitat that was lost and it was some of the best habitat. The river used to run black with fish. A lot of people say it was commercial fishing, maybe it was but there has always been commercial fishing. There used to be a commercial fishery will right at the mouth of the Klamath where they had a cannery. Even then there was a lot of salmon but they also let salmon go through back then. That's how the Karuks do now, we make sure that plenty of salmon have passed through to the spawning grounds. That's why we don't fish until the salmon have gotten through to Inam, so you would have fish for the next year.
>
> One thing I never hear people talk about... it's the responsibility of the Karuk people to fish. We have fish, we do fish medicine and it's our responsibility if we want to make it to the other side to take care of fish. They are a spiritual food for our people. That dam blocks the river and blocks the way to that good spawning habitat for the salmon. That's a concern that I have that nobody even talks about but according to our old stories the spirit people that we come from made that river. They drug that river all the way up there for one reason or another before we came into existence so and we still do our ceremonies. We still believe we're Karuk. You got to believe that stuff you know that's our... that's who we are. It's our job to take care of our fish. That's why I think the dams shouldn't be there. They should have never been there.

What happened with the fish is that over the years the native fish slowly vanished so now there is hardly any and they are mostly all hatchery fish now that are going back to Iron Gate which is as far as they can go. With the dam gone maybe they will go on, hopefully they will go on up. It seems like the hatchery fish will turn native after so many years and go on up there into the new habitat. I think taking the dams out will make the river healthy again, or healthier. There are a lot of people who don't want the dams out. I’ve noticed the decline in fish over the years. Some years there are pretty good runs, every year at least one good run will come through where there's just fish everywhere, but if you aren't down there in that three or four days when they come through you miss it. So a lot of times people might not even be down there fishing. Right now the fish are at the mouth of the Salmon River waiting for the water to cool down, but I don't know if they are at the falls were not. There's a pretty good run coming through right now but nothing compared to the past. I'm surprised really in some of the big fish that have come through, but we have had high water this year. Some years it's a lot better than others. I think this year is going to be a good fish year, but I feel bad when we catch a female out of the river now even though we're supposed to eat fish to stay healthy. We were told by our grandfathers that if we didn't eat fish, fish won't be here anymore. Maybe that's the only reason they are still here, who knows. They have a hard time getting here -- all the boats and nets and fisherman... I hope I don't come back as a fish (laughs). They would be catching me right off the bat.

I think they should be the tribe's concern spiritually, we have to answer to the Creator if we want to go back across to the other side. They might come get you, and they might send you back if you don't do the right thing here. That's what they told me. So regardless of what everybody else thinks, the right thing from our perspective would be to give the fish their habitat back so... they never ever should have put the damn thing in there. They did conference with people way back then before the dams were put in and some of the old Indians didn't want to put the dams there, but they didn't hardly listen to them than, probably still don't unless you've got a good environmental buddy (chuckles). So the damn dams are no good and everybody knows it so I don't know why we keep talking about it even.

Our spiritual beliefs are hard thing to talk about, because everybody has beliefs. You go talking about stuff like that and sometimes it angers people. According to my grandma and according to her grandfather, we were here first. We helped the Creator make all the stuff. Maybe every tribe has its own way of looking at things. I believe those stories myself, if you do make it to the other side you have to answer to the way you support the dance. The white guys don't find it logical, “Just dam it up." (Laughs) There is a river on the other side that has salmon as big as marlin. I had dreams about it when I was a kid. Grandma said when you get there they have a big celebration and it reminds you of what it was like when you were here. They have Indian houses all over the river and everything is spiritual of course with celebrating and singing and they are happy that you're there. They come across and get you in a canoe, or they send you back. If we can't believe that, we can't even believe in our ceremonies, right? I believe you can go there when you're on the mountain for 20 days and your spirit leaves your body. We travel back there. I'm sure of it. That's it in a nutshell. We have to take the dams out so the fish can survive. That's our perspective, the farmers have their own perspective of course.

They used to be a flat rock by the falls long time ago and it got covered up by the floods but people used to go there and make fish medicine. That's why when I was a kid I wanted to be a fisherman. Grandma didn't want me to be a fisherman. You do a lot of work in your jumping around down there when your youngster even when you're not fishing. In the old days it was dangerous just getting out to where we fish, there were a lot of big back streams when there was a lot of water, but I got hooked on it. That's what I did, I packed poles for Willis until I finally got to dip. They were big poles then and then they started making these little flyweight poles for skimming fish off the top of the water. They were nice, but you have to use some finesse when you use the light poles because they will break. You don't really muscle the fish with them until you get them in the right place, then you turn the net over to hold them.

There used to be runs all summer. These days they are up there around the first of September. Maybe they are waiting for that moon, I just know they do pretty much the same thing every year. They used to come up earlier when there was more fish. In the last 10 years you can pretty much count on them being down there by Labor Day weekend. I used to go down there way before that a long time ago. We would go down there August 15 and start catching fish. And then all of a sudden there wouldn't be any until 1 September and we would have been down there for two weeks fishing and never catch nothing, maybe a steelhead that you're supposed to throw back. Now after the first of September a run will come through for about three or four days and then the run is gone. Then you wait and another run will come through, all through September usually. We're getting smaller and smaller runs in a shorter time. I don't go how it will be this year, we've had more water and there might be more fish. I have wish I would have gotten as smart as a fish but I never ate enough of them when I was little. When I was young we would eat the little ones live so that we could think like a fish. They told us you have to be able to be as smart as a fish to catch them, so you have to eat a lot of the little fish and fish heads too. We used to eat fish brains all the time. You wind up being a good fisherman if you believe in it. But I believe in all that stuff, all those stories. There's a whole bunch of different reasons for them. It all has to do with good management and taking good care of the earth. Grandma said we have the birthright to be there and we have the birthright to understand that.

-Harold Tripp

3.6.1.2.1 Trade and barter

Native American trading networks were very extensive and well established prior to the arrival of Europeans in California. An indication of this extensiveness is in the fact that many people knew of the arrival of Europeans some 15 years before they actually appeared in Northern California. Based on information received through trading networks and contact with the Hudson's Bay Company, native people were aware of the types of goods the European traders would be interested in, furs and skins, and also knew that in return for these native commodities they could expect to receive highly valued metal implements, such as knives and cooking pots. On the Klamath River, Hudson Bay trappers traded apple trees to the local Native Americans in return for the right to trap. They also supplied seeds which quickly resulted in widespread gardening by the Klamath River natives. Prior to this Karuk land management had largely consisted of cool burns to eliminate brush and pruning of certain food sources such as oak trees to maximize production of forest products for native utilization.

Trading networks not only allowed tribes to obtain resources which were relatively scarce in their own territory, but also developed alliances and solidarity between tribes. Coastal tribes traded highly valued dentalium shells which served as currency and could be made into beads for inland materials such as obsidian and soapstone. Trading networks facilitated the development of increasingly sophisticated and complex social and cultural elements of the various tribes prior to the arrival of Europeans. At its population peak, California was home to more than 300,000 Native Americans. This population was to plunge precipitously with the arrival of European diseases and devastating levels of warfare waged against the native inhabitants.

Trading sites in neutral territory allowed for regular and peaceful trading between the different tribes. Trading also furthered development of complex societies made up of richer and poorer families and individuals. Food was an important object of trade and tribes including the Karuk traded the plant and animal foods of their territory with coastal tribes for fish and objects such as Redwood canoes. Native women were regularly married out into other tribes in order to promote alliances. In preparation for this process of marrying out, young women were regularly taught the rudiments of other regional languages in order to give them a linguistic basis for establishing themselves as married women in tribes speaking languages other than those they were raised with. Among the Karuk, the Flower Dance was an occasion for the teaching of multiple languages to young women in preparation for their future as wives living in other tribes.

There were a number of social mechanisms which allowed trading to take place, including specialist traders who traveled from tribe to tribe, as well as the presence of trading sites which facilitated trading between tribes. Trading also took place within tribes. Among the Karuk there were 10 identifiable family groups each managing its own area. Each of these management areas which had different commodities in varying levels of abundance which resulted in trading between the different management areas. In the Aikens Creek area of Karuk territory, five different languages were spoken among the permanent villages located in this area which facilitated trading with other language groups. As a rule of thumb, there was a customary goal of having a stock of two years of a given resource in order to account for years in which that particular resource might be scarce. Beyond this protective goal of having a resource base to fall back on, materials in surplus were suitable objects of trade. This was a system of trade based upon a principal of having sufficient surplus of a resource to allow it to be considered suitable for trading. Trading of goods such as iris fiber twine for obsidian or pine nuts was always subject to negotiation. These negotiations assured a compassionate element in trading relations to ensure that those individuals and groups who were relatively lacking in certain materials would not be taken advantage of in the trading process.

The natural diversity of the Klamath basin offered a particularly wide range of potential resources which could be considered appropriate for trading with other tribes, once a level of surplus had been reached.

Religious Practices

As the purpose of this document is to examine the effect of the Klamath Hydroelectric Project on the cultural and natural resources of the Karuk Tribe, and as the details of the major Karuk ceremonies have been described in detail in Kroeber and Gifford, these ceremonies will be discussed in the present context for the insights they provide into the cultural life and underlying values of the Karuk, and in their linkage to the other tribes of the river in a shared cultural complex, i.e. an ethnographic riverscape. In one aspect, the ceremonies, as with other aspects of traditional perspective, are reenactments of acts of the ikxar’eeyavsa or immortal ones. In another sense these ceremonies go beyond symbolic reenactments and are themselves metaphors for close and careful husbanding of resources, of hard work, of making your own luck in the tradition of Karuk individualism, and of the seasonal lack of resources available to the people, even with the most careful of ritual observations.

The Karuk are known among Indian tribes of the western United States as “the Fix-the-World People.” This term is derived from the annual Piky’avish Ceremonies, commonly referred to as the World Renewal Ceremonies. This sequence of ceremonies is shared by the Karuk with the downriver Yurok and Hupa Tribes. The timing of the Piky’avish was related to the fall salmon run and at the time approaching the acorn harvest. The dance cycle is determined each year by a ceremonial leader or headman who also appoints the fatav’eenan for that year. This appointment is at the same time a source of honor and great labor, as the fatav’eenan is required to undergo a lengthy ordeal including fasting, praying, and walking the Medicine Trails.

Traditionally the Piky’avish was preceded by the Jump Dance held at the Dance Village of Amekiarum (Ameeky’aaoqam), a short distance downriver from Ka’tim’iin, site of the White Deerskin Dance. The Jump Dance was held at the time when the spring salmon began their run and was initiated by the First Salmon Ceremony.

Powers gives the following account of the First Salmon Ceremony:

> …They celebrate it to insure a good catch of salmon. The Kareya (ikxariya’‘arrar) Indian [priest] retires into the mountains and fasts the same length of time as in autumn. On his return the people flee, while he repairs

> to the river, takes the first salmon of the catch, eats a portion of the same, and with the residue kindles the sacred smoke in the sudatory. No Indian may take a salmon before this dance [used in the sense of a ceremony] is held, nor for ten days after it, even if his family is starving (Powers p. 31).

Although the Piky'avish is an annual ceremony whose conclusion marks the Karuk New Year and is celebrated with great joy and feasting, the Deerskin Dance is held on years alternating with the Medicine Dance during which other decorated skins including martin and otter are displayed rather than the famous white deerskins. The Karuk ceremony has three major aspects:

> The first is a period of usually not more than ten days during which the priest remains much in the sweathouse, fasts, and prays for abundance of food, the elimination of sickness and the stability of the world. He also visits sacred spots; and young men engage in archery contests. The second part is the climax of the ceremony, when the priest keeps an all-night vigil by a sand pile called yuxpit. This vigil is accompanied and followed the next day, by the Deerskin Dance, or its surrogate, an imitation affair employing branches instead of deerskins; at Inam and Ka'tim'iin the War Dance is part of the dance ritual. The third part is the anticlimactic retreat of the priest and other officials (Kroeber and Gifford p.6).

The archery shooting aspect of the Piky'avish referred to in the above statement is a contest of shooting at a small fork shaped target (yu'xpiit) set in front of a screen of fir branches and which is often hidden from the shooter behind brush or shrubs, requiring that the shot be angled up sharply so that the falling arrow will land vertically, as the goal is to "wake up the earth" for iky'avish and the new year. The occasion of arrow shooting is one of prayerful concentration followed by exuberant competition with small bets being placed on each round. The winner of a match shoots first in the subsequent match and then goes to a place where he can call out to the remaining shooters where their arrow has fallen in relation to the target. On subsequent days the archers move from location to location, in the sequence preordained by the Ikxar'eeyavsa. In acts of abstinence, concentration and purification reminiscent of the purifications required for deer hunting, the arrow shooters fast from the previous night, neither eating nor drinking water. Following a prayer by the Headman which includes a statement propitiating health "even for the creatures that crawl," the shooters make medicine (p'irish) feeding a pinch of tobacco crumbled into a medicine fire and making a war cry in the direction of a sacred peak designated by the Headman while uttering a phrase in Karuk calling for a long life.

One of the earliest accounts of the World Renewal Ceremonies is that of Stephen Powers (1877). In the following statement Powers simultaneously sets forth the ideas central to these ceremonies, their emotional sensibilities and the unity of the Karuk, Yurok and Hupa, as well as other tribes joined in this occasion of paramount ritual, celebratory and ecological significance.

> The first of September brings a red-letter day in the Karok ephemeris, the great Dance of Propitiation, at which all the tribes are present, together deputations from the Yurok, the Hupa, and others. They call it sif'-san-di pik'i'a'vish, (thivthaaneen piky'avish)) (at Happy Camp, su-san-ni nik-I-a-vish), which signifies, literally, 'working the earth" (I will work). The object is to propitiate the spirits of the earth and the forest, in order to prevent disastrous landslides, forest fires, earthquakes, drought, and other calamities (Powers, p. 13).

Georgia Orcutt captures the emotional nature of the piky'avish as follows: "At the beginning of the Piky'avish, it looks like everything down, nobody happy. Piky'avish means making the world right. Fatawanun (fataveenan) fixed it so everything is coming up nice (Kroeber and Gifford p.8).

Oral Traditions

The presence of dams on the Klamath River has been a significant factor in the decline of salmon runs in this river. This decline of a central resource for the Karuk people has also had a widespread effect on many aspects of Karuk culture. While the decline of fishing stock is a consequence of multiple factors reaching back into the 19th century, Karuk people often cite the placement of Iron Gate Dam as a final decisive factor in the devastation of the once spectacular salmon runs of the Klamath River. Because the dams did cause the salmon runs to significantly drop, they also caused a decline in certain activities which were related to the plenitude of salmon. The Karuk language has, like the salmon moved to the brink of extinction. With the decrease in the number of salmon spawning in the upper Klamath basin, as well as the decrease in the variety of runs of spawning salmon, came a closely linked decrease in cultural activities related to the salmon. The consequence of the decline of salmon as a resource has been a decline in activities and ceremonies relating to the salmon, including the decline in the spoken Karuk language.

The culturally significant spring salmon ceremonies cannot be held if there are no spring salmon. Many historic elements have weighed heavily upon Karuk culture. These include the near extinction of the Karuk language. Following the arrival of Europeans in North America and prior to their actual physical presence in the Klamath River country, Karuk people were incrementally forced to live a different life through a combination of disease and various levels of oppression. The Karuk language was so intricately tied to the traditional life that as the Karuk stopped living traditionally, they stopped using their traditional language, bit by bit. This is something of a co-emergent situation. When the Karuk stopped using their language certain traditional activities ceased and conversely when certain traditional activities ceased, the falling away of the language was accelerated.

A range of types of losses of traditional culture can be related to the presence of the dams as well as other factors which came with the arrival of Europeans in the Klamath region of northern California. These losses include the devastation of the culture, the loss of territory, the decline in health and the near loss and extinction of the language of the pre-invasion people of the Klamath River. The oral tradition was too central to traditional life to be maintained in the face of this multilevel onslaught, part of which was forcing the Karuk to use another language. Karuk children were punished in the public schools for using even a single word of their traditional language. Decades after the nineteenth century practice of forcibly removing children from their homes and placing them in schools where their contact with their families was largely limited to summer vacations, Karuk elders still recall being spanked with rulers and having their mouths washed out with lye soap when a public school teacher overheard them speaking as much as a single word of the Karuk language. An important element in maintaining traditional culture is related to the use of the traditional Karuk language. The Karuk language declined precipitously from the 1930s through the first half of the twentieth century. Even with the dams in place, the Karuk have for better than a decade worked to recapture and master their traditional language with an acute awareness of the centrality of language in culture.

This resurgent interest in language is, in a way, a precursor to changes in the cultural environment of the Karuk, including removal of the dams. With removal of the dams, linguistic elements will already be in place to fit into this important change in the Karuk environment. Among the Karuk, the importance of language restoration makes removal of the dams important in their lives. There is a widespread awareness of this relationship between language and the environment and Karuk leaders in the struggle to remove the dams are also leaders in language restoration.

In the 1930s ceremonial leaders recognized that the ability to speak fluently in the traditional Karuk language was being lost. In order to preserve the integrity of tribal ceremonies, these ceremonies began to be conducted in English. This was a conscious compromise in the face of the potential loss of ceremonies, if only those who spoke fluent Karuk were able to participate. The linguistic adjustment of conducting ceremonies was flexible response to a situation of overwhelming enforced change. Everything is translatable, but important elements of culture are lost in the translation. There remains a subtle sense of loss connected with the loss of traditional language.

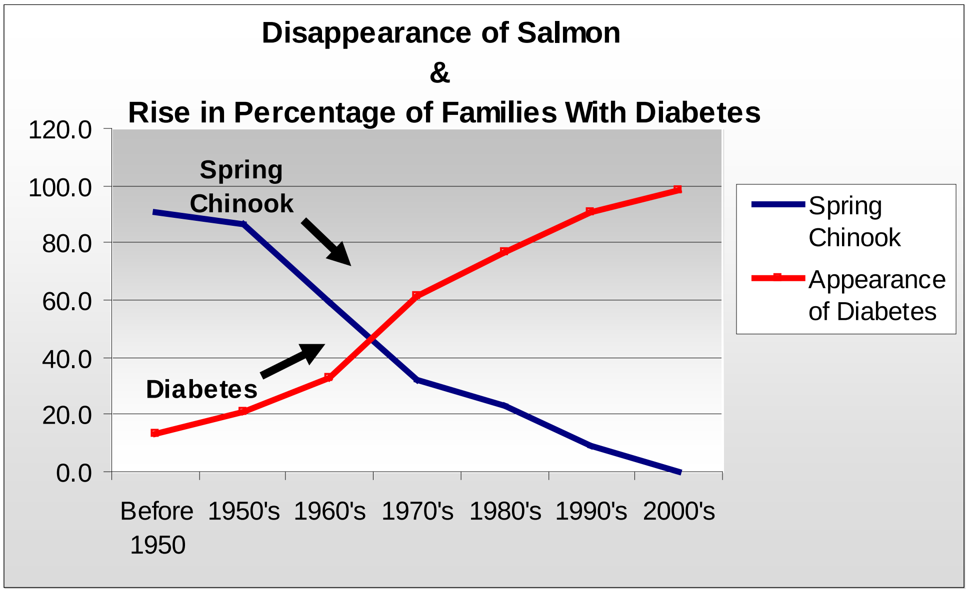
Anthropological literature does little to address this situation, in part because those traditional Karuk who felt strongest about what amounted to a linguistic imperialism, frequently did not cooperate with ethnographers. Karuk people born in the 1870s, who lived to well into the second half of the 20th century, stated repeatedly that those whose knowledge of the culture was greatest simply refused to cooperate with ethnographers, while others of lesser knowledge would, for a price make up elaborate cultural fictions as a form of entertainment for themselves and their observing friends. This is not to say that the early ethnographers did not capture important information, but it is to say that in the oral tradition there was an early and deep form of resistance to the objectification of their language and culture by ethnographers. Ms. Bessie Tripp of the Salmon River recalled that one could always tell by the length of the presentation, the magnitude of the tale being woven as a traditional story for the ethnographer while observers would maintain a stoic face while bursting with laughter at the ridiculous things that ethnographers would accept on face value. Kroeber commented in a footnote in the “Handbook of the Indians of California,” Mrs. Bessie Tripp of the Salmon River knows fish medicine but wants five dollars for it." It seems clear that Krober never gained access to this particular piece of fish medicine.

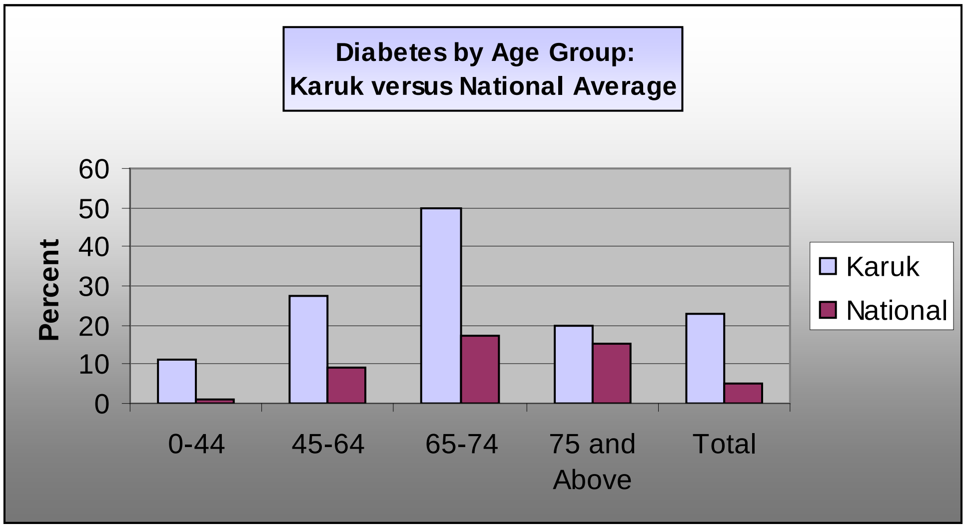
Health Impacts

While early anthropologists described the Klamath River tribes as some of the wealthiest people in California, since contact they have become some of the poorest. Currently the Klamath corridor has some of the highest rates of hunger in the state of California and lowest incomes. Local populations have traditionally had much of their food supplied by the Klamath River. This continues to be the case, but with the decline in river health this becomes increasingly difficult. Given the economic impoverishment of the region, there is no general access to healthy alternative foods withough subsistence fishing and gathering. As a result, there is a hunger dimension related to the presence and effects of the dams that is very significant and is connected to the traditional subsistence economy.

Spring Chinook salmon represented a large volume of health food for the Karuk People until the 1960's and 1970's. Despite the fact that rates are now 4 times the U.S. national average, diabetes is a recent occurrence in the Karuk population. In the 2005 Karuk Heath and Fish Consumption Survey we asked Tribal members when diabetes first appeared in their family. This graph shows the close association between the disappearance of this food source and the rise of diabetes in Karuk Families.

Karuk families were asked a) when did diabetes first appear in your family and b) when did spring salmon stop playing a significant role in your family's diet. As shown by the graph below, over 90% of reporting families say that before 1950 spring salmon playing a significant role in the family diet and less than 15% reported occurance of diabetes. By 2005, no families claimed spring salmon played a significant role in the family diet and nearly 100% reported occurrences of diabetes (Norgaard 2005).





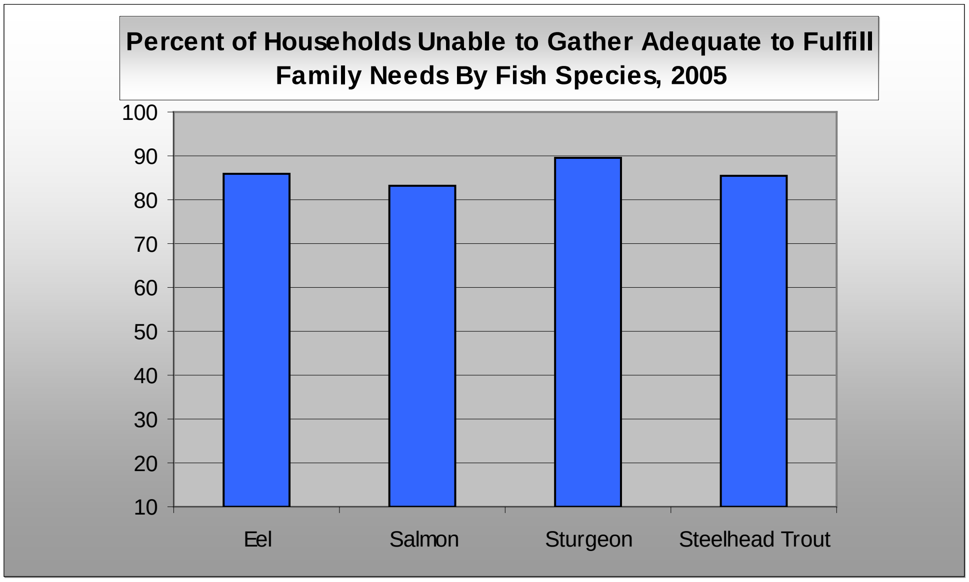
The diet related diseases that have recently appeared in the Karuk population at such alarming rate are costly. According to a recent study by the American Diabetes Association, the nation spends $13,243 in health care costs every year on each person with diabetes, compared to $2,560 per person for people who don't have diabetes (American Diabetes Association, 2003). Direct costs include expenses such as doctor visits, medications, hospitalizations, hospice care and emergency room visits. These are not the only costs of these conditions. Applying the best available data on average national expenditures of $13,243 to the number of Karuk tribal members living in the ancestral territory with diabetes in 2004 (394 individuals) yields an annual cost of over 5.2 million dollars (Norgaard, 2005).

Culturally there are many activities that are connected to the spring salmon. These are cultural and ritual activities that cannot occur without the presence of the species. Other activities that are very affected by the dams are specifically linked to water quality. For example, there is a need for the medicine man to be drinking from and bathing in the Klamath River at the very time when we know it is most contaminated by algal toxins. So there is a whole cultural dimension to the presence of the dams that is very important to the Karuk people and culture. There is also social dimension to this loss. In the past, when the native fishery at Ishi Pishi falls was thriving, Karuk people would come together for the fish and associated ceremonies. Families would see each other, children would see their friends for the first time since the previous year's ceremonies. People came from out of the area, stories are shared when people were gathered at the ceremonies, so there is an intergenerational aspect of what happens when there are fish in the river. While this discussion has focused most specifically on the salmon, there are other species that are important and discussions at the ceremonies fall within a highly defined and sacred context.

The anthropological literature of the early 20th century describes how mussels were gathered late in the season when the river flows were low. The time of year that they would be contributing to ceremonies is the exact time of year when they are highest in microcystin, a hepatotoxin associated with cyanobacterial blooms in the reservoirs, so that is a new development that is very significant. But there are also people who are still using freshwater mussels as a food source, but again there is less and less of this food source. There has not been as much attention paid to mussels as there has been to the spring salmon. As a result of recent research, there has been a resurgence of interest and awareness in these issues and we find that mussels are contaminated at the time of year that people are most likely to be gathering and using mussels in ceremonial ways. This is another species in addition to salmon that is particularly important. The sense of ceremonial celebration is replaced by a deep sense of anguish and loss.

There is a loss of a sense of pride in being able to be a food provider as a salmon fishermen, and this pertains to other species as well. There is a sense of pride in having an identity and a role and doing what you were put here to do by the Creator, versus what happens to people's psychology and emotional and mental health when they are unable to fulfill that role. There is a huge mental health component to being able to provide, versus when you are not able to provide. There is a shame of not having a space to fit into, especially for young people. This relates to the dams, because the dams are responsible for a lack of spawning habitat and are changing the river systems in many ways. They are changing water quality, water temperature, flow regimes-all the traditional pieces in the system are having an impact on what is happening in the river below. The river has changed in ways that are not appropriate for species to flourish. In addition to these ecological phenomena, there is all of the human activity that cannot take place that ought to take place-that has been taking place for thousands of years which makes humans part of a functioning social, economic cultural health system. This long-standing system has been directly impacted by the presence of the dams.

> You can give me all the acorns in the world, you can get me all the fish in the world, you can get me everything for me to be an Indian, but it will not be the same unless I'm going out and processing, going out and harvesting, gathering myself. So I think that really needs to be put out on mainstream society that it's not just a matter of what you eat. It's about the intricate values that are involved in harvesting these resources, and how we manage them for these resources and when.
>
> -Ron Reed, Traditional Karuk Fisherman



While there are the cultural practices which are impacted, there are also social roles within families, where children and elders interact across families through barter and the provision of food to people outside the family. There are the health aspects of eating the fish, including the exercise of getting fish. There are significant psychological and mental health aspects to the presence of a healthy fishery. In the subsistence economy of the Karuk, food from the river is not just food, but it is healthy food. One of the significant pieces in this whole story is that of environmental justice. The indigenous people of California have experienced forced assimilation, which is still ongoing through various mechanisms. One of the mechanisms through which forced assimilation happens is that many people probably try to hide their native identity in order to survive. As a result, a profound misunderstanding about the existence of native people in California exists. For the native people, one of the ways they experience racism is an invisibility to the powers of government. The fact of their invisibility makes it almost impossible for members of the various agencies who are trying to review these projects to understand what is going on. They really don't comprehend that there are people eating out of the river whose culture and lives are so intimately connected with the river and with the health of the river. This inability places Native people at another disadvantage in addition to all of the other factors, including the lack of resources. The assumption is that people do not eat their food and drink water out of the forest and the rivers. In Humboldt County many Native Americans and others as well are eating and getting their water out of the forests. But the way that the management practices are so culturally restrictive insures that those controlling the resources do not comprehend the people they are affecting. Because of this cultural invisibility, there are few explicit attempts to make space for these practices and the associated cultures.

Damming of the River

Published in 1931, but with research initiated in 1919, John O. Snyder of Stanford University wrote what he termed a “digest of the work accomplished in a salmon investigation conducted under the authority of the Bureau of Commercial Fisheries of the California Division of Fish and Game” (Snyder, 1931). Snyder quotes from an undated paper by R.D. Hume who reported:

> In 1850 in this River during the running season, salmon were so plentiful, according to the reports of the early settlers, that in fording the stream it was with difficulty that they could induce their horses to make the attempt, on account of the River being alive with the finny tribe. At the present time the main run, which were the spring salmon, is practically extinct, not being enough taken to warrant the prosecution of business. The River has remained in a primitive state, with the exception of the influence which mining has had, no salmon of the spring run having been taken except a few by Indians…and yet the spring run has almost disappeared, and the fall run

> reduced to very small proportions, the pack never exceeding 6000 cases, and in 1892 the River produced only 1047 cases (Ibid. p.19).

Although nearly a century has passed since this research was conducted, Snyder's discussion includes dynamics that are still impacting Klamath River salmon. He refers to the fact that in this period not only were observations of depletion ignored, some even claimed that salmon runs were "gradually building up." This is an early example of a recurring tendency of vested interests on the Klamath ignoring the reality of what was happening to fish stocks, in order to promote their own positions-in this case the interest is that of concerns in commercial fishing.

Snyder cites the original depletion of Klamath salmon, following arrival of non-Native people to the area around 1850, to have been the taking of large numbers of spawning salmon by spears and other means as reported by the "old miners." By 1912 three processing plants with no restrictions had been located in the vicinity of the mouth of the Klamath.

In a statement prefiguring current environmental opinion by 75 years, Snyder asserts, "The fishery of the Klamath is particularly important, however, because of the possibility of maintaining it…(Ibid.)". This is a comparative evaluation as Snyder foresees development of the reaches of the Sacramento River in all its forms - commercialization, damming of tributaries, irrigation of the valley, pollution and the introduction of competitive species. As we have seen, in fact, Snyder's assessment has proven to take in the range of negative impacts, with the exception of introduced competitive species.

Snyder also makes what must be one of the first scientifically framed references to the effect damming had on both minimum flows in summer, as well as the control of "the violence of spring freshets", which are at other points in this paper discussed as having been vital for flushing out the bottom of the River and the maintenance of cold water refugia in the Klamath, which has always presented potentially lethal temperatures to migrating anadromous fish in times of low water and high temperatures without cold water refugia. (Ibid p. 19). Snyder further observes, based on interviews with fishermen and "old residents", that prior to Copco Dam's becoming operational on October, 25, 1917, "large numbers of salmon annually passed the point where Copco dam is now located" (Ibid.).

Snyder was not shy about extrapolating from the circumstances of his time to what might occur to the River in the future:

> The Klamath River and its principal tributaries are fairly free from obstructions below the large dam at Copco. Projects have appeared in the recent past, which if carried through would have blocked the stream to most of its migrating fish. Others will come in the future, and eventually the anadromous fish may disappear from the River (Ibid. p.50).

In a statement prescient of the failed mitigations that accompanied the construction of the Copco dams and the later Iron Gate Dam, Snyder observed:

> Certain articles have lately appeared in current periodicals which allege that experimental work has conclusively shown that the obstacles presented by high dams to the migration of fish may be easily overcome. These statements are misleading. No method has as yet been devised which will safely provide for the downward migrants…
>
> In the Klamath River a condition prevails that must be constantly kept in mind in any discussion of the relation of dams and fish, namely that the principal migrations occur during low water, and when the water is in greatest demand by the power plant. At this time it will be very difficult to maintain an overflow sufficient for large fishways. The Klamath River has a relatively limited amount of irrigable land in its basin and consequently the problems attending a conflict between agriculture and the conservation of fisheries may not attract attention there for some time… (Ibid. pp.51-52).

Snyder was understandably unable to fully anticipate the development of agricultural lands in the upper Klamath Basin, accomplished by the draining of the Klamath wetlands. The loss of this great wetland area and the several major ecological functions played out by these wetlands has proven to play a major role in the environmental and political controversy accompanying Klamath River management at this time.

Dam Removal

Removal of the four Klamath River dams which are the subject of this Environmental Impact Report (EIR) will make available a significant amount of new habitat with the result of increased diversity of salmon species and a multiplicity of new salmon runs which will mirror the nature and diversity of runs prior to the installation of Iron Gate dam. The local economy will benefit from increased sports fishing opportunities and the availability of diverse runs will benefit the overall long-range viability of the Klamath salmon. The resulting diversity of runs will be reflected in the overall physical health of the Karuk people who continue to be dependent on the river for their most important source of nutrition.

The construction of the Copco I and Iron Gate dams in the mainstem Klamath River is solely responsible for the termination of anadromous fish runs of salmon, steelhead and lamprey into the Upper Klamath Basin. In addition, the construction and current operation of the five hydroelectric and re-regulating dams constructed in the Mainstem Klamath River, beginning with Iron Gate Dam at the furthest downstream site through Link River Dam, impede or totally obstruct the movement and restrict the range of resident fish within and beyond the inter-dam reaches of the Klamath River.

With the construction of a series of dams beginning in 1917 and with the completion of Copco Dam No. 1, salmonids were completely blocked from access to more than a hundred miles of spawning grounds in the Upper Klamath Basin. Some years earlier, but in the same historical period of agricultural expansion, earlier constructions, including the Chiloquin dam, began this process of limiting access of anadromous fish to the Upper Klamath River Basin. In addition to this loss of spawning habitat, the construction of Copco and subsequent dams was accompanied by greatly increased agricultural draws on available water. Drainage of these new agricultural lands contributed to increased concentrations of nutrients in the Klamath River. Downstream of Iron Gate Dam, the impacts to anadromous species include the quality of water released from Iron Gate in critical low flow periods. Water quality changes include temperature, and the addition of nutrients through Upper Klamath Basin agricultural practices.

Despite mitigations, hatcheries and countless studies, by 2003 the Klamath River has become the second most endangered of the country's River systems. The report of American Rivers, a Washington, D.C. based conservation group, attributes the continuing decline in the state of the River to too many irrigation diversions and dams, citing the present runs as constituting less than 10% of historic numbers. This report, like others of the past year cites too much water as having been irresponsibly been promised to too many interests.

The conclusions of this report as to the dire status of the fishery, as well as the complex set of environmental, regulatory and economic issues involved, closely resembles the assessments of the Karuk people and water quality experts interviewed for this paper and referred to in historic and scientific bodies of information. The fish, which were once plentiful beyond any sense of potential depletion, are now either threatened or nearing extinction, and will certainly be so in the near future unless a real examination of the situation and decisive acts replace the political and economic argumentation of the past few decades.

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A PETITION TO THE STATE OF CALIFORNIA
FISH AND GAME COMMISSION

For action pursuant to Section 670.1, Title 14, California Code of Regulations (CCR) and Sections 2072 and 2073 of the Fish and Game Code relating to listing and delisting endangered and threatened species of plants and animals.

I. SPECIES BEING PETITIONED:

Common Name: Klamath Trinity Spring Chinook, Upper Klamath-Trinity River spring Chinook

Scientific Name: (*Oncorhynchus tshawystscha*)

II. RECOMMENDED ACTION:

(Check appropriate categories)

a. List X b. Change Status ☐

As Endangered X from
As Threatened ☐ to

Or Delist ☐

III. AUTHORS OF PETITION:

Name: Russell "Buster" Attebury, Chairman

Address: Karuk Tribe
PO Box 1016
Happy Camp, CA 96039

Email: battebery@karuk.us

Phone Number: 530.493.1600

I hereby certify that, to the best of my knowledge, all statements made in this petition are true and complete.

Signature: Rll A. Attebury

Date: 7-16-18

III. AUTHORS OF PETITION:

Name: Karuna Greenberg

Address: Salmon River Restoration Council
25631 Sawyers Bar Road
Sawyers Bar, CA 96027

Email: karuna@srrc.org

Phone Number: 530.462.4665

I hereby certify that, to the best of my knowledge, all statements made in this petition are true and complete.

Signature:

Date: 7/20/2018

PETITION TO THE STATE OF CALIFORNIA FISH AND GAME COMMISSION SUPPORTING INFORMATION FOR

Klamath Trinity Spring Chinook,
Klamath Trinity spring-run Chinook
Upper Klamath-Trinity River spring-run Chinook
Upper Klamath-Trinity River Spring Chinook (*Oncorhynchus tshawystscha*)
Common Name **Scientific Name**

EXECUTIVE SUMMARY

Petitioners Karuk Tribe and Salmon River Restoration Council submit this petition to list the Upper Klamath Trinity River Spring Chinook (*Oncorhynchus tshawytscha*) hereinafter referred to as UKTR Spring Chinook, as an endangered species under the California Endangered Species Act (CESA) pursuant to the California Fish and Game Code §§ 2070 et seq. This petition demonstrates that the UKTR Spring Chinook warrants listing under CESA based on the factors specified in the statute.

In 2011, Center for Biological Diversity (CBD) et al. filed a Federal Endangered Species Act (ESA) listing petition (2011 Petition) with the National Marine Fisheries Service (NMFS) to address the dramatic declines of Upper Klamath-Trinity River (UKTR) spring-run Chinook salmon. The petition was denied due to NMFS' belief that scientific evidence did not warrant reclassification of the spring-run component of UKTR Chinook as its own Evolutionarily Significant Unit (ESU) under the Endangered Species Act (ESA). However, new evidence demonstrates sufficient differentiation between the spring-run component of UKTR Chinook, referred to here as UKTR Spring Chinook, and their fall-run counterparts, to warrant the UKTR Spring Chinook's classification as its own ESU. On that basis, the Karuk Tribe and Salmon River Restoration Council petitioned NMFS on November 2, 2017 to reconsider its decision and list the UKTR Spring Chinook as endangered. The evidence supporting the Federal listing also supports listing the UKTR Spring Chinook as an endangered species under CESA.

UKTR Spring Chinook used to be abundant in Klamath Watershed and are important to the culture, health, and economy of the Karuk Tribe. Their survival as a species in California is threatened due to the destruction of their habitat or range, construction of dams and water diversions, disease, predation, non-existent or limited regulations, and other causes. Further information on the plight of the UKTR Spring Chinook is detailed below and in the 2011 Petition. Both the 2011 Petition and the 2017 Petition to NMFS are attached hereto and incorporated by reference. The condition of the UKTR Spring Chinook has deteriorated further since the rejection of the 2011 Petition.

For purposes of this document, UKTR Spring Chinook refers to all spring run Chinook salmon in the Klamath Basin. Within this document, UKTR Spring Chinook may also be referred to by the following names: spring-run Chinook, spring run Chinook, spring Chinook, Upper Klamath spring Chinook, UKTR spring Chinook, Trinity spring Chinook.

UKTR Spring Chinook survival is threatened by any one or a combination of the following factors (as listed in Section 670.1, Title 14, CCR):

(1) present or threatened modification or destruction of its habitat;

Historically, UKTR Spring Chinook over summered and spawned in the Williamson, Sprague, and Wood River systems of southern Oregon (Hamilton et al. 2005). The construction of a complex of hydropower dams between 1917 and 1962 created a barrier to fish passage near the California/Oregon border, effectively denying salmonids access to approximately half the Klamath Basin ("Klamath Facilities Removal

Final Environmental Impact Statement/Environmental Impact Report" 2012). Young's dam on the Scott River and Dwinnell Dam on the Shasta River also serve to deny access to historic UKTR Spring Chinook habitat (Moyle et al., 2017).

Between 1870 and the 1950's large scale placer mining, including hydraulic and dredge mining, severely altered critical spawning and rearing habitat for UKTR Spring Chinook in the middle Klamath and its tributaries. One of the most important factors leading to the decline and continued low abundance of coho and UKTR Spring Chinook is the legacy effect of historical placer mining on channel and floodplain habitat conditions throughout the mainstem and larger tributaries of the Klamath River (Stumpf 1979). Hydraulic and dredge placer mining in the Salmon River between about 1870 and 1950, for example, led to profound and lasting changes, eroding over 1,859 acres adjacent to the mainstem and larger tributary channels and delivering an estimated 20.3 million cubic yards of sediment to the river (Hawthorne 2017, de la Fuente and Haessig 1993). Placer mining denuded floodplains and adjacent river terraces and hillslopes, reduced riparian shade cover, and exposed the stream channel and surrounding areas to increased solar radiation. (Stillwater Sciences 2018)

In addition, numerous irrigation projects throughout the Klamath Basin impact fish passage, impair water quality, and impair river and stream flows, all of which contribute to decline of UKTR Spring Chinook populations.

(5) disease;

In 2014 and 2015, 81% and 90% of juvenile Chinook salmon sampled were infected with the lethal parasite *Ceratonova shasta*. These high rates of infection were the result of poor water quality, low flows, and prolonged absence of flushing flows necessary to scour the river bed (Hillemeier et al. 2017). These observations led Tribes and conservation groups to file suit against the Bureau of Reclamation and National Marine Fisheries Service resulting in re-consultation on the Klamath Irrigation Project operations plan.

(6) other natural events or human-related activities.

As noted above, a century of dams, diversions, and mining has been a leading cause of UKTR Spring Chinook declines.

1. POPULATION TRENDS

Long-term population abundance data are limited for anadromous Klamath River salmonids. The earliest data primarily consist of catch records for Chinook salmon from early 20th century canneries (NMFS 2009). The data and information on Chinook salmon indicate that population levels have declined significantly since the early 20th century. NMFS 2009 review of all Klamath Basin salmonids reports that, "despite the lack of cohesive long-term data sets to assess population trends, the data that do exist indicate significant population declines in all species throughout the 1900s, leading to a current state of low abundance. Currently, a significant portion of Chinook salmon and Coho salmon that return to spawn in the Klamath River Basin are fish that were spawned in hatcheries" (NMFS 2009).

Spring run

UKTR Spring Chinook salmon in the Upper Klamath Basin are at extremely low abundances compared to their historical status and their current low numbers make them vulnerable to extinction. This is stated clearly in the recent status review of salmon, steelhead, and trout in California:

> The numbers of spring Chinook in the Klamath and Trinity River have remained at low levels for the past 20 years with no obvious trends, but numbers are so low…that extirpation is a distinct possibility (Moyle et al. 2008).

Similarly, NMFS (2009) acknowledges the compromised status of spring runs in the Klamath Basin based on their unique life history and the resulting dangers to survival:

> Spring run Chinook salmon enter the Klamath River from April to June of each year before migrating to smaller headwater tributaries. They require cold, clear rivers and streams with deep pools to sustain them through the warm summer months. These areas have been greatly reduced in the Basin due to dams and degradation of habitat. The spring Chinook salmon run was historically abundant and may have been the dominant run prior to commercial harvest commencing in the mid-1800s. Wild spring run Chinook salmon populations are now a remnant of their historical abundance and primarily occur in the South Fork Trinity River and Salmon River Basins (NMFS 2009)

UKTR Spring Chinook were historically abundant in the Klamath River Basin and have since declined significantly due to a variety of threats. Moyle et al. (2008) state, "while it is likely that UKTR spring Chinook were historically the most abundant run in the Klamath and Trinity Rivers (Snyder 1931, LaFaunce 1967), by the time records were being kept seriously, they had been reduced to a minor component of Klamath salmon." In the past, populations of spring-run Chinook in the Basin likely totaled over 100,000 fish (Moyle 2002). The spring run was apparently the main run of Chinook salmon in the Klamath River until it declined steeply in the 19th century as a result of hydraulic mining, dams, diversions and fishing (Snyder 1931).

In each of four main Klamath tributaries (Sprague, Williamson, Shasta, and Scott Rivers), historic run sizes were estimated by CDFG (1990) to be at least 5,000. The runs in the Sprague, Wood, and Williamson Rivers were probably extirpated in 1895 after the construction of Copco 1 Dam (Moyle et al. 2008).

In 1968, efforts to maintain a UKTR Spring Chinook run through artificial propagation of native stock at the Iron Gate Hatchery began (Klamath Task Force 1991). During the 1970s, approximately 500 fish returned each year to the hatchery but these attempts were eventually unsuccessful as the hatchery was unable to maintain the run without a source of cold summer water (Hiser 1985, Moyle et al. 2008).

The Shasta River run, probably the largest in the middle Klamath drainage, disappeared in the early 1930s as a result of habitat degradation and blockage of access to upstream spawning areas caused by Dwinnell Dam (Moyle et al. 2008). The Scott River spring run was extirpated in the early 1970s after a variety of human causes led to depleted flows and altered habitat (Moyle 2002). Along the middle Klamath River, UKTR Spring Chinook are extirpated from their historic habitat except in the Salmon River (NRC 2004). Less than ten spring-run Chinook return annually to Elk, Indian, and Clear Creeks (Campbell and Moyle 1991).

Moyle et al. state that "UKTR spring Chinook have been largely extirpated from their historic range because their life history makes them extremely vulnerable to the combined effects of dams, mining, habitat degradation, and fisheries, as well as multiplicity of smaller factors" (2008). By the 1980s, UKTR Spring Chinook were largely eliminated from their habitat due to the loss or lack of access to the cold, clear water and deep pools they required for survival (NRC 2004). Spring-run Chinook in particular must contend with low flows and high temperatures during up and down-river migrations that can prevent them from reaching their destinations or significantly increase mortality during migration (Moyle et al. 1995, Trihey and Associates 1996).

In the Trinity River, UKTR Spring Chinook runs above Lewiston Dam included more than 5,000 adults in the Upper Trinity River and 1,000-5,000 fish each in the Stuart Fork Trinity River, East Fork Trinity River and Coffee Creek (CDFG 1990). These runs are now extinct. Over about the last thirty years, an average of 263 fish have been counted annually in the South Fork Trinity River, with runs as low as 59 (1988, 2005) and as high as 1,097 (1996). Between 1980 and 1989, an average of 142 spring-run Chinook were counted annually in the South Fork Trinity River; 351 fish between 1990 and 1999; and most recently 232 between 2000 and 2005. Historically, 7,000-11,000 UKTR Spring Chinook entered this stream (LaFaunce 1967) and outnumbered fall-run Chinook in the watershed. Between 1980 and 2004, an average of 18,903 UKTR Spring Chinook returned above Junction City on the main stem Trinity River. In 2004, 16,147 UKTR Spring Chinook were estimated to migrate into this area with 6,019 (37%) of fish entering Trinity River Hatchery classified as spring-run Chinook (Moyle et al. 2008). Trinity River Hatchery releases over one million juvenile spring-run Chinook every year and apparently all spawners in the main stem Trinity River are of hatchery origin (NRC 2004).

Hatcheries have severe negative effects on wild populations and are considered a high threat to both spring- and fall-run Upper Klamath Chinook (NMFS 2009, J. Katz pers. comm. 2010). Interactions between wild and hatchery fish influence abundance, spatial distribution, life history diversity and productivity. For more details on the threat of hatcheries in the Basin, see "hatcheries" in the discussion of threats in this petition. The Trinity River population of UKTR Spring Chinook is highly affected by hatchery fish and cannot be considered a viable wild population. Moyle et al. explain,

> Essentially, the only viable wild population today is in the Salmon River. Other populations are either small and intermittent or heavily influenced by hatchery fish, so may not be self-sustaining and are likely to be extirpated in the near future (Moyle et al. 2008). Spring run Chinook populations in the Salmon River, exhibit high variability among years. The 2005 adult count estimate was 90 fish, the lowest on record, but in 2007 the number reached 841 (Moyle et al. 2008) and in 2009, it was 643 (CDFG personal communication). In Wooley Creek, escapement has ranged between 0 and 81 during 1968-1989, but more recent surveys suggest spring run Chinook are nearly extinct in this watershed. In 2005, only 18 spring run Chinook were observed (Moyle et al. 2008).

The National Research Council (2004) also noted the low abundance and limited distribution of spring-run Chinook in the Klamath Basin, especially those of wild spawning origin:

> In the Klamath River drainage above the Trinity, only the population in the Salmon River and Wooley Creek remains; it has annual runs of 150– 1,500 fish (Campbell and Moyle 1991, Barnhart 1994). Numbers of fish in the area continue to decline (Moyle 2002). Because the Trinity River run of several thousand fish per year is apparently sustained largely by the Trinity River Hatchery, the Salmon River population may be the last wild (naturally spawning) population in the basin.

Moyle et al. point out the current reliance of the spring run on this dwindling Salmon River population as they make conclusions about the status of the species:

> Overall, while UKTR Spring Chinook salmon are still scattered throughout the lower Klamath and Trinity basins, the only viable wild population appears to be that in the Salmon River. Trinity River fish numbers are presumably largely influenced by fish from the Trinity River hatchery. Even if Trinity River tributary spawners are considered to be wild fish, the total number of UKTR Spring Chinook in the combined rivers rarely exceeds 1000 fish and may drop to <300 in many years (2008).

In the 2008 status review, Moyle et al. report that the UKTR Spring Chinook are “vulnerable to extinction in the next 50-100 years” based on the “fluctuating nature and small size of the Salmon River population and its localized distribution in a single watershed.”

This report produced the following table:

Table 1.

Metrics for determining the status of Upper Klamath/Trinity River spring Chinook salmon, where 1 is poor value and 5 is excellent.

Metric	Score	Justification
Area occupied	2	Multiple populations exist including hatchery populations but only Salmon River is viable
Effective population. size	2	Although there is a hatchery stock, there are few natural spawners support the population.
Dependence on intervention	3	Hatchery program in Trinity is probably maintaining the Trinity run. The Salmon River wild population is vulnerable to extinction from both local and out-of-basin events. More human intervention necessary to preserve Klamath stock by re-establishing populations.
Tolerance	2	Temperature and other factors in summer holding areas may exceed physiological tolerances.
Genetic risk	2	Hybridization may be occurring in some watersheds with fall run fish; populations are low enough so genetic problems can develop.
Climate change	1	The Salmon River has temperatures in summer (21-23°C) that approach lethal temperatures. A 1-2°C increase in temperature could greatly reduce the amount of suitable habitat.
Average	2.0	12/6
Certainty	3	Monitoring efforts by USDA Forest Service, CDFG, tribes and local organizations give us reasonable information about status.

Spring-run Chinook are listed as a Species of Special Concern by California Department of Fish and Wildlife and are thus qualified to be added to the state and federal lists of threatened or endangered fish (Moyle et al. 2008). They are also considered a Sensitive Species by the Pacific Southwest Region of the US Forest Service.

Should NMFS choose not to consider the spring run of Upper Klamath Trinity River Chinook as a separate ESU or DPS, the threatened status of the spring run within the current ESU is enough rationale for listing the entire current ESU under the Endangered Species Act. Protecting the spring run from extinction is essential to maintaining the diversity of the existing ESU regardless of whether the ESU is redefined or a spring-run Chinook DPS is acknowledged. By NMFS precedent, an entire ESU may be listed under the ESA based on the threat to one of the life histories that composes it. According to Bilby et al. (2005), the loss of many of the spring-run Chinook salmon populations from the Lower Columbia River ESU was one of the factors supporting the NMFS decision to list the ESU as threatened (NOAA 2003). The same is true of the Puget Sound Chinook ESU.

In describing foreseeable long-term trends for UKTR Spring Chinook, Moyle et al. conclude:

> UKTR spring Chinook have declined from being the most abundant run in the basin, to being a tiny run in danger of extinction. There are multiple possible futures for this distinctive salmon. The two extremes are extinction and restoration to a large segment of its historic range. At the present time it is headed for extinction. Climate changes will lead to increased water temperatures and fluctuations in many portions of the basin. Without drastic management measures, climate change will likely be the final blow to wild spring Chinook in the Klamath Basin. The run will then simply be a remnant hatchery run in the Trinity River for a few decades before it finally becomes so introgressed with the fall run so that it loses its genetic and life history distinctiveness. Alternately, there is potential for UKTR spring Chinook salmon to be restored to large portions of the Klamath basin through a few decades of restoration of habitat and habitat access (e.g., Shasta River, upper Klamath Basin) (2008).

UKTR Spring Chinook require immediate protections under the Endangered Species Act if they are to persist in the Klamath Basin.

Fall run Chinook

Compared to current numbers of Chinook salmon in the Upper Klamath and Trinity Rivers, runs were much larger historically (NRC 2004) and low abundance predictions of Klamath River fall Chinook in recent years have forced severe harvest restrictions to West Coast fisheries (NMFS 2009). The vast majority of the fish today are fall-run fish of both wild and hatchery origin" (NRC 2004) and most records of Chinook salmon abundance in the Basin were taken after the initial decline of spring-run Chinook and therefore historical estimates tend to refer primarily to the fall run (Moyle et al. 2008). NMFS (2009) refers to sizable historic estimates in the Basin: "Based on records of commercial harvest, fall run Chinook are likely to have numbered 400,000 to 500,000 in the early 1900s. Runs in the last several decades have ranged from below 50,000 to 225,000 fish. These runs are substantially lower than historic levels." Snyder (1931) provided an early estimate of 141,000 fish, based on the 1912 fishery catch of 1,384,000 pounds of packed salmon. Moffett and Smith (1950) then estimated the Klamath River Chinook runs to be about 200,000 fish annually, from commercial fishery data from between 1915 and 1943. USFWS (1979) combined these statistics to approximate an annual catch and escapement of about 300,000 to 400,000 fish for the Klamath River system from 1915-1928 (Moyle et al. 2008).

The National Research Council (2004) reviewed historical estimates of fall Chinook:

> …the river harvest alone in 1916–1927 was 35,000–70,000 fish (as estimated from Snyder's data showing an average weight of 14 lb/fish and a harvest of 500,000– 1,000,000 lb each year). If, as Snyder's data suggest, the river harvest was roughly 25% of the ocean harvest in this period, annual total catches were probably 120,000–250,000 fish. This in turn suggests that the number of potential spawners in the river was considerably higher than the number spawning in the river today. Since 1978, annual escapement has varied from 30,000 to 230,000 adults. In both 2000 and 2001, runs were over 200,000 fish. If it is assumed that fish returning to the hatcheries are, on the average, 30% of the population and that 30% of the natural spawners are also hatchery fish, then roughly half the run consists of salmon of natural origin (including progeny of hatchery fish that spawned in the wild).

At the Klamathon Racks, a fish counting station close to the location of Iron Gate Dam, an estimated annual average of 12,086 Chinook were counted between 1925-1949, and the number declined to an average of 3,000 between 1956-1969 (USFWS 1979). In 1965, the Klamath River Basin was reported to contribute 66% (168,000) of Chinook salmon spawning in California's coastal basins (CDFG 1965). This production was distributed between the Klamath (88,000 fish) and Trinity (80,000 fish) basins, with approximately 30% of the Klamath Basin fish originating in the Shasta (20,000 fish), Scott (8,000 fish), and Salmon (10,000 fish) Rivers (Moyle et al. 2008). Snyder (1931) recorded the Shasta River as the best spawning tributary in the basin. It has since seen a marked decline in the number of fish returning. Leidy and Leidy (1984) estimated an annual average abundance of 43,752 Chinook from 1930-1937; 18,266 between 1938 and 1946; 10,000 between 1950 and 1969; and 9,328 from 1970-1976. A review of recent escapement into the Shasta River found an annual escapement of 6,032 fish from 1978-1995, and an escapement of 4,889 fish between 1995 and 2006 (CDFG 2006). In the Scott River, fall Chinook escapement averaged 5,349 fish between 1978 and 1996 and 6,380 fish between 1996 and 2006 (Moyle et al. 2008).

The National Research Council (2004) notes the drop in the population in the Shasta River as an important contributor to the overall decline of Upper Klamath Chinook:

> Additional evidence of decline is the exclusion of salmon from the river and its tributaries above Iron Gate Dam in Oregon, where fairly large numbers spawned, and the documented decline of the runs in the Shasta River. The Shasta River once was one of the most productive salmon streams in California because of its combination of continuous flows of cold water from springs, low gradients, and naturally productive waters. The run was probably already in decline by the 1930s, when as many as 80,000 spawners were observed. By 1948, the all-time low of 37 fish was reached. Since then, run sizes have been variable but have mostly been well below 10,000. Wales (1951) noted that the decline had multiple causes, most related to fisheries and land use in the basin, but laid much of the blame on Klamath River lampreys: the lampreys preyed extensively on the salmon in the main stem when low flows delayed their entry into the Shasta River.

In the Trinity River, Coots (1967) estimated an annual run of about 80,000 fish. Hallock et al. (1970) reported about 40,000 Chinook salmon entered the Trinity River above the South Fork. Burton et al. (1977 in USFWS 1979) estimated that 30,500 Chinook below Lewiston Dam on the Trinity River escaped between 1968 and 1972. The average fall Chinook run in the Trinity River between 1978 and 1995 was 34,512. This average declined between 1996 and 2006 to 23,463 fish (CDFG 2007).

The total in river escapement into this ESU ranged from 34,425 to 245,542 fish with an average 5-year geometric mean of 112,317 fish between 1978 and 2006 (Moyle et al. 2008). A large proportion of these fish are of hatchery origin and therefore do not contribute, and even constitute a threat, to the long-term persistence of Chinook salmon in the Basin and (Bilby et al. 2005).

Hatcheries have played a major role in fall-run Chinook salmon abundance since the 1960s (Moyle et al. 2008). Approximately 67% of hatchery releases have been fall-run Chinook from Iron Gate and Lewiston hatcheries (Myers et al 1998). Between seven and twelve million juveniles have been released annually (NRC 2004). Between 1997 and 2000, an average of 61% of the juveniles captured at the Big Bar outmigrant trap were hatchery origin fish (USFWS 2001) and at the Willow Creek trap on the Trinity River, between 1997 and 2000, 53% and 67% of the Chinook captured in the spring and fall were hatchery-origin fish, respectively (USFWS 2001). Some naturally-spawning fish are actually hatchery strays. Based on coded wire tag expansion multipliers, as much as 40% (Shasta River) of annual escapement consists of hatchery strays (R. Quinones, unpublished data as cited by J. Katz, pers. comm. 2010). As this region becomes dominated by hatchery fish, wild fish are threatened by greater competition, predation, disease transmission, and reduced fitness due to interbreeding with hatchery fish. As a region becomes dependent on hatchery fish, its ability to recover as a wild-spawning population of fish is highly compromised (ISAB 2005)

Upper Klamath-Trinity River fall-run Chinook are a US Forest Service Sensitive Species. They are managed by CDFW for sport, tribal, and ocean fisheries.

According to the Moyle et al. (2008) status review, fall-run Chinook have declined from historical numbers of between 125,000 and 250,000 fish returning annually to the Basin to an average run size of about 120,000 since 1978 (from tables compiled by CDFG). Numbers in the past 25 years have sometimes reached this historical range but lower numbers are now typical and current runs depend heavily on hatchery production. Fall-run Chinook have experienced a major downward trend in recent years, especially as a result of the 2002 fish kill in the lower river. Climate change will lead to even more threatening conditions for this ESU (Barr et al. 2010).

The Moyle et al. status review summarizes the long term trends for Klamath Basin Fall-run Chinook and reports:

> There is little reason to be optimistic about long-term trends in the future without major changes in watershed management. High summer water temperatures are a major driver of UKTR Chinook survival and they are likely to increase under most climate change scenarios. Likewise, changes in ocean conditions may cause decreased survival of fish once they leave the river (Moyle et al. 2008).

The report also points out that the increased reliance of the fall run on hatchery production is “likely masking a decline of wild production in the Klamath-Trinity basins”. Moyle et al. cited a 2005 report stating, “models evaluating limiting factors and habitat availability for UKTR Chinook salmon suggest that crucial steps need to be taken soon to increase UKTR fall Chinook spawners” (citing Bartholow and Henrikson 2005).

The National Research Council acknowledges that while fall-run Chinook have declined significantly, they may be good candidates for recovery under the right management reporting, “the fishery of the Klamath is particularly important…because of the possibility of maintaining it (NRC 2004). NRC goes on to note that both adults migrating upstream and juveniles moving downstream face water temperatures that are bioenergetically unsuitable or even lethal and that the vulnerability of the run to stressful conditions was dramatically demonstrated by the mortality of thousands of adult Chinook in the lower river in late September 2002.

Both spring- and fall-run Chinook have declined in the Klamath Basin with spring-run Chinook demonstrating the most drastic trends of reduction. The spring run requires protections under the ESA in order to avoid extinction. Maintaining the spring run is essential to supporting the diversity of the current ESU and the vulnerability of this run in particular could justify listing the entire Upper Klamath-Trinity Rivers ESU according to the ESA.

2. RANGE AND DISTRIBUTION

Spring- and fall-run Chinook distributions have been affected differently by conditions in the Basin because spring-run Chinook enter freshwater earlier than fall-run Chinook, and historically traveled much greater distances upstream (Hamilton et al. 2005).

Spring-run Chinook salmon were historically found throughout the Klamath Basin. They used suitable reaches in the larger tributaries such as the Salmon River and, flows permitting, they also accessed smaller tributaries for holding and spawning. They were once especially abundant in the major tributary basins of the Klamath and Trinity Rivers, such as the Salmon, Scott, Shasta, South Fork and North Fork Trinity Rivers (Moyle et al. 2008). Spring run Chinook were once also widely distributed throughout the Basin above the current sites of dams, attaining holding and spawning grounds on the Sprague, Williamson and Wood Rivers above Upper Klamath Lake (Moyle et al. 2008). This habitat was blocked below Klamath Falls in 1912 by construction of Copco 1 Dam (Hamilton et al. 2005).The construction of Dwinnell Dam in 1925 on the Shasta River eliminated access to UKTR Spring Chinook habitat in that watershed.

Currently, only the Salmon River, a major freshwater tributary to the Klamath River, maintains a viable population in the Klamath River Basin (Moyle et al. 2008). Approximately 177 km (110 mi) of habitat is accessible to spring-run Chinook in the Salmon River (West 1991) but most of it is underutilized or unsuitable (Moyle et al. 2008). The South Fork Salmon River holds the majority of the spawning population but smaller tributaries where spring Chinook redds have been found in the Salmon River Basin include Wooley,Nordheimer, Knownothing, and Methodist Creeks. In addition, there are dwindling populations of spring Chinook in Elk, Indian, Clear Creeks (Moyle et al. 2008).

In the Trinity River Basin, spring Chinook salmon once spawned in the East Fork, Stuart Fork, Coffee Creek, and the main stem Upper Trinity River (Campbell and Moyle 1991). The construction of Lewiston Dam in 1964 blocked access to 56 km of spawning and nursery habitat on the main stem Trinity River (Moffett and Smith 1950).

Currently, Trinity River spring Chinook are present in small numbers in Hayfork and Canyon Creek, as well as in the North Fork Trinity, South Fork Trinity and New Rivers (Moyle et al. 2008). The Trinity River Hatchery releases over 1 million juvenile spring run Chinook every year, usually in the first week of June. Apparently, all spawners in the main-stem Trinity River below Lewiston Dam are of hatchery origin (NRC 2004).

The distribution of fall-run Upper Klamath Chinook has been less affected by dam construction because of their lower reliance on upstream spawning habitat. They are found in all major tributaries above the confluence of the Klamath and Trinity rivers and in the river main stems (Moyle et al. 2008). Fall-run Chinook return to both Iron Gate and Trinity River Hatcheries.

Upper Klamath fall Chinook salmon once ascended to spawn in habit, now-blocked, in middle Klamath tributaries (Jenny Creek, Shovel Creek, and Fall Creek), and in rivers in the Upper Klamath Basin, especially in wetter years (Hamilton et al. 2005). On the lower Klamath River, tributaries providing suitable spawning habitat include Bogus, Beaver, Grider, Thompson, Indian, Elk, Clear, Dillon, Wooley, Camp, Red Cap, and Bluff Creeks (Moyle et al. 2008). The Salmon, Shasta and Scott Rivers were historically and remain among the most important spawning areas for fall-run Chinook, when sufficient flows are present. Spawning consistently occurs in the main stem Klamath River between Iron Gate Dam and Indian Creek, with the two areas of greatest spawning density typically occurring between Bogus Creek and the Shasta River and between China Creek and Indian Creek (Magneson 2006).

On the Trinity River, UKTR Spring Chinook once ascended above the site of Lewiston Dam to spawn as far upstream as Ramshorn Creek and historically, the majority of Trinity River fall Chinook spawning was located between the North Fork Trinity River and Ramshorn Creek. Currently, spawning is confined to the approximately 100 km between Lewiston Dam and Cedar Flat (Moyle et al. 2008). Important historic spawning tributaries above Lewiston Dam include the Stuart Fork, Browns and Rush Creeks (Moffett and Smith 1950). The distribution of redds in the Trinity River is highly variable (Moyle et al. 2008). The reaches closest to the Trinity Hatchery contain significant spawning but there is great variability in use of spawning habitat in reaches between the North Fork Trinity River and Cedar Flats (Quilhiullalt 1999)**.** Additional tributaries contain spawning fall-run Chinook salmon in the Trinity River including the North Fork, New River, Canyon Creek, and Mill Creek (Moyle et al. 2008). In the South Fork, fall-run Chinook once spawned in the lower 30 miles up to Hyampom, and in the lower 2.7 miles of Hayfork Creek (LaFaunce 1967).

The distributions of both the fall and spring runs of UKTR Chinook have contracted since the end of the 19th century. Because of the unique life history of the spring run, it has been most damaged by these changes, directly causing extirpation of several populations and making the run vulnerable to future genetic introgression with the other life history type in the Basin.

3. ABUNDANCE

Please see #1, Population Trend.

4. LIFE HISTORY (SPECIES DESCRIPTION, BIOLOGY, AND ECOLOGY)

A. Life Cycle and Physiology

The Chinook salmon life cycle begins when an adult female prepares a nest, called a “redd,” by digging in a stream area with suitable gravel type, water depth and water speed (McCullough 1999). Body size, which is related to age, may be an important factor in migration and redd construction success. All Chinook salmon tend to use spawning sites with large gravel and significant water flow through the gravel. Deep water with sufficient sub-gravel flow is essential to provide oxygen to the eggs and remove metabolic waste. Thus, limited sub-gravel flow resulting in low oxygen concentrations are linked to egg mortality (Allen and Hassler 1986). Excess silt in the water can also block water flow through gravel (Healey 1991).

Female Chinook lay 2,000 to 17,000 eggs, each about nine millimeters in diameter (Healey 1991). One or more males then release sperm into the redd before females cover it with gravel (Allen and Hassler 1986). Once the eggs have been fertilized, adult Chinook guard the nest briefly (up to a month) before dying. Egg mortality can result from limited oxygenation, extreme temperatures, predation and toxic chemicals (Healey 1991). Depending on water temperature, the eggs will hatch three to five months after being laid, which ensures young salmon (termed “alevins”) emerge when river conditions are best.

Alevins remain in the spawning habitat for at least two to four weeks until their yolk sacs are completely used. Like the eggs, Alevins require adequate water flow through the gravel for growth and survival (Nawa and Frissell 1993). Once the alevin consumes its yolk sac, it enters the fry-fingerling stage and begins feeding and socializing. Some fry remain in the spawning grounds, while others begin their tail-first migration to the ocean soon after emerging from the redd. A number of factors such as water flow, food availability, temperature and competition may influence when the fry and fingerlings migrate.

The vast majority of juvenile fall Chinook migrate within one year of hatching whereas the majority of spring Chinook migrate after one year. Moyle et al. (2008) reports on a study by Sullivan (1989) which identified three distinct types of juvenile freshwater life history strategies for UKTR fall Chinook. The majority of fish fall into the first and second categories: 1) rapid migration following emergence, and 2) tributary or cool-water area rearing through the summer and fall migration. A small percentage of fish were in a third category, which remained in freshwater through winter and migrated to the estuary as yearlings.

Juvenile Chinook undergo smoltification, a physiological transformation that prepares the fish for the increased salinity in the ocean (Weitkamp 2001). Fall Chinook grow to smolt size near the end of their time in the estuary, whereas spring Chinook turn into large smolts before they reach the estuary (Healey 1991). The amount of time a juvenile salmon spends in freshwater varies. Some male Chinook salmon mature in freshwater while others spend less than a year in freshwater, depending on genetic and environmental factors (NRC 2004). Juvenile fall-run Chinook spend less than a year in the fresh water of the Klamath River Basin, allowing the juveniles to avoid unfavorable late summer stream conditions (Healey 1991, Moyle 2002). Spring-run Chinook however, spend at least one year in freshwater before migrating to the ocean (Healey 1991).

The majority of spawners returning to the Klamath River Basin are age three fish. This reflects heavy mortality of older and larger fish in ocean fisheries. Some four, five, and six year old fish are found spawning (Moyle et al. 2008). Some fish return from the ocean within two or three months, in the case of a small number of yearling males (called jack salmon). These jack salmon constituted 2-51 percent of the annual Klamath River Chinook salmon numbers between 1978 and 2006 (Game 2006 as cited in Moyle et al. 2008)

In the ocean, Klamath River Chinook salmon are found in the California Current system off the California and Oregon coasts. Moyle et al. (2008) reports that salmon follow predictable ocean migration routes. Chinook recaptured from the Klamath River generally use ocean areas that exhibit temperatures between 8° and 12°C (Hinke et al. 2005). Chinook salmon from the Klamath and Trinity hatcheries were observed in August south of Cape Blanco (Brodeur et al. 2004).

Adult Chinook return to freshwater to spawn and die. During ocean residence, salmon build up stores of body fat and cease feeding during upstream migration. Spring-run Chinook, enter the Klamath River between March and July and spawn between late August and September, while fall-run Chinook enter the river between July and October and spawn between September and January (Myers et al. 1998).

The timing of upriver migration into freshwater and spawning of Chinook salmon is likely defined by water temperature and flow regimes. For example, data collected primarily from Columbia River migration suggests that spring Chinook migrate at 3.3-13.3ºC and fall Chinook migrate at 10.6-19.4ºC (McCullough 1999).

In general, salmon runs today occur later than they did historically. The current fall run of Chinook occurred earlier and was known as the summer run in the past (Snyder 1931). For example, Moyle et al. (2008) reports that run timing on the Shasta and Klamathon Racks appears to occur one to four weeks later than historic run timing. Although run timing has responded to accommodate warmer stream conditions, temperatures are likely still stressful to migrating salmon and may result in increased mortality of spawning adults (NRC 2004).

Chinook rely primarily on olfaction memory and partially on sight to find their way back to their natal stream. Some evidence suggests that fall Chinook seem to have a stronger homing instinct than spring Chinook (Healey 1991). Adults primarily migrate during the day, which exposes them to higher temperatures that may inhibit their migration or increase mortality. After spawning, adult females defend their eggs; thereafter both male and female salmon deteriorate rapidly, often developing a fungal disease, and die within 2-4 weeks (Allen and Hassler 1986).

Spring Chinook

The variation of life history between spring and fall Chinook is relevant to the difference in status between the runs. Many of these are shown below, in Table 1. Unlike fall Chinook, spring Chinook in the Klamath River Basin utilize streams and tributaries a great deal during their life cycle. Juveniles usually reside in streams for at least one year before migrating to the ocean (Healey 1991). These juveniles are much more dependent on freshwater stream ecosystems because of their extended residence in these areas.

Spring Chinook adults return to the Klamath River between March and July before their gonads have fully developed (Moyle et al. 2008). The majority of late entry spring Chinook in the Klamath system are of hatchery origin (Barnhardt 1994, NRC 2004). Moyle et al. (2008) note a study which identified adult Trinity River spring Chinook migration continuing until October. They argue however that given this late timing, it is unclear if these fish are sexually mature and able to spawn with spring Chinook adults already in the system. Also, they report, that because this late spring run is limited to the Trinity River, it is possible these fish represent hybrid spring and fall Chinook created by hatchery practices (Moyle et al. 2008).

Spring adults typically hold in deep (greater than two meters) freshwater pools for 2-4 months to allow their gonads to develop before spawning (NRC 2004). These behaviors allow spring Chinook salmon to spawn much further upstream than fall Chinook, who must contend with higher temperatures and lower flows in the lower Klamath during the late summer months (Moyle 2002). Spring Chinook spawning peaks in October.

After emerging from the redds between March and early June, spring Chinook fry remain in the same cold headwaters as holding adults for the summer (West 1991). Some juveniles migrate downstream beginning in October, but most remain in the headwaters until the spring (Trihey and Associates 1996).

Spring Chinook typically spend more time in freshwater streams, both during their downriver and spawning migrations. They are therefore more vulnerable to adverse stream conditions. The increased time spent in streams and greater distance of migration are disadvantages to survival in the current system because spring Chinook experience low flows and high temperatures during migration that can prevent them from reaching their destinations and significantly increase mortality during migration (Moyle et al. 1995, Trihey and Associates 1996).

Table 2.

Summary of Life Cycle and Physiological Differences between Spring and Fall Chinook in the Upper Klamath River Basin

	Spring Chinook	Fall Chinook	Citations
Adult migration immigration	Between March and July with a peak between May and early June. Spring Chinook migrate before reaching sexual maturity and holdover in deep (greater than two meters) freshwater pools for 2-4 months prior to spawning.	Between mid July and late October. Migration and spawning occur under decreasing temperature regimes.	Barnhart 1994, NRC 2004, Myers et al. 1998, Moyle et al. 2008
Holding elevation	Historically, overlap of spawning areas was rare between spring and fall Chinook because spring Chinook spawned well upstream of fall Chinook before the construction of dams. Spatial separation between the two runs in the Klamath-Trinity system occurs at approximately 1,700 feet	Downstream of 1,700 feet elevation (must contend with higher temperatures and lower flows during migration in the late summer months.	Moyle 2002, Moyle et al. 2008
Spawning	Begins between late August and September, peaks in October.	Between September and January.	Myers et al. 1998, Moyle et al. 2008
Emergence from gravel	Between March and early June, remain in the same cold headwaters as holding	Late winter or spring, timing dictated by water temperature.	Trihey and Associates 1996, Moyle et al. 2008

	adults for the summer.		
Juvenile out-migration	Some juveniles migrate downstream beginning in October, but most remain in the headwaters until the spring.	Most juveniles reside >one year in fresh water, allowing them to avoid unfavorable late summer stream conditions. Between 1997-2000, wild juveniles were observed in the lower river in the beginning of June with a peak in mid-July.	West 1991, Moyle et al. 2008

B. Diet

Chinook salmon diet varies depending on growth stage. As alevins, the young fish rely on nutrients provided by the yolk sack attached to the body until leaving the redd after a few weeks. After emerging from the gravel, young fry begin to feed independently. Juveniles feed in streambeds before gaining strength to make the journey to the ocean. During this time, fry feed on terrestrial and aquatic insects and amphipods.

As juveniles migrate toward the ocean, they may spend months in estuarine environments feeding on plankton, small fish, insects, or mollusks. Small fry feed primarily on zooplankton and invertebrates, while larger smolts feed on insects and other small fish (ie: chironomid larvae, chum salmon fry and juvenile herring; Healey 1991).

Juvenile Chinook salmon can feed and grow at continuous temperatures up to 24ºC when food is abundant and conditions are not stressful (Myrick and Cech 2001). In the late summer, juveniles seek out cooler temperatures in refuge pools along the Lower Klamath River, where they may experience intraspecies competition for food.

At sea, where the bulk of feeding and growth is done, adult Chinook typically feed on small marine fish, crustaceans, and mollusks (i.e., squid). Adult Chinook grow quickly in the estuary and gain body mass during their time at sea, building fat reserves that are required for upstream migration and spawning. During the upstream migration, Chinook do not feed and rely on stored energy while traveling hundreds of miles.

5. KIND OF HABITAT NECESSARY FOR SURVIVAL

The variety of habitats Chinook salmon encounter means that they require a number of particular conditions in order to survive and reproduce. Chinook salmon in the Klamath-Trinity River Basin occupy the main stem rivers and tributaries during migration, spawning, and rearing. They also occupy the estuary and open ocean for variable time periods during maturation. Chinook salmon habitat use and requirements are best studied for their time spent in freshwater although ocean conditions are also significant to the survival and viability of these populations.

Migration and Spawning habitat

Upper Klamath Chinook salmon migrate from the open ocean to spawning habitat, typically to the same place where they hatched. During this time, they are in a stressed condition due to their reliance on stored energy to complete the long journey upstream, leaving them highly susceptible to additional environmental stressors. This was clearly a factor during the 2002 fish kill when inadequate stream flows, temperature conditions, and the resultant crowding of fish led to disease outbreaks and mass mortality. Chinook salmon require access to spawning habitat in the main stem rivers and tributaries, cold water, cool pools in which to hold, clean spawning gravel, and particular dissolved oxygen levels, water velocities, and turbidity levels in order to successfully migrate and spawn. Access to spawning habitat is threatened by physical conditions including the existence of impassable dams, which caused the extirpation of several populations of spring run Chinook. Also, the ongoing variability in water flows does not allow Chinook salmon to access certain streams for spawning.

During migration and spawning, low water temperatures are crucial to success of Chinook salmon. Under warm conditions, salmon cease their upstream migration and instead hold in cooler pools. Upper Klamath spring Chinook enter the Klamath estuary during a period when river water temperatures are at or above optimal holding temperatures (Moyle et al. 2008). In June, temperatures in the Lower Klamath River typically rise above 20°C and can be as high as 25°C in August (Moyle et al. 2008). Prior to entering fresh water, Spring Chinook use thermal refuges in the estuarine salt wedge and associated near shore ocean habitat (Strange 2003). Strange (2005) found that when daily water temperatures were on the rise, Chinook migrated upstream until temperatures reached 22°C; when temperatures were decreasing, fish continued to migrate upstream at water temperatures of up to 23.5°C. Optimal adult holding habitat for spring Chinook is characterized by pools or runs greater than one meter deep with cool summer temperatures (<20°C), all day riparian shade, little human disturbance, and underwater cover such as bedrock ledges, boulders, or large woody debris (West 1991). Because the Salmon River and its forks regularly warm to summer daytime peaks of 21-22°C, presumably the best holding habitats are deep pools with cold water sources, such as those at the mouths of tributaries, or are deep enough to be subject to thermal stratification (Moyle et al. 2008). Due to the typically higher flows during spring Chinook migration, Salmon River spring Chinook are typically able to move high into the system, allowing them to reach areas with more optimal river temperatures, however this is not as feasible during drought years. UKTR fall Klamath fall Chinook salmon enter the Klamath estuary for only a short period prior to spawning. However, unfavorable temperatures can be found in the Klamath estuary and lower river during this period and chronic exposure of migrating adults to temperatures of even 17°-20°C is detrimental (Moyle et al. 2008). Optimal spawning temperatures for Chinook salmon are less than 13°C (McCollough 1991) and fall temperatures are usually within this range in the Trinity River (Quilhillalt 1999). Magneson (2006) reported water temperatures up to 14.5°C during spawner surveys in 2005. The Shasta River historically was the system’s most reliable spawning tributary from a temperature perspective (Snyder 1931), but diversions of cold water have greatly diminished its capacity to support salmon (Moyle et al. 2008).

According to McCullough (1999), adults are more sensitive to higher temperatures than juveniles, as higher temperatures can increase the adults’ metabolic rate and deplete their energy reserves, weaken their immune system, increase exposure to diseases, and prevent migration. Also, temperatures at or above 15.6ºC can increase the onset of diseases (Allen and Hassler 1986). Riparian vegetation is critical as it provides much needed shade to cool the water (Moyle 2002) and creating “thermal refugia” in which fish can escape high temperatures. The presence of cold water in the Basin is threatened by dams, water withdrawals, as well as logging and grazing which decrease riparian vegetation.

Spring Chinook migrate earlier before their gonads are fully developed and then hold in deep cool pools before spawning. Therefore, the presence of deep cold-water pools is essential to the survival of spring-run fish in particular. Dams, water withdrawals, logging, mining, and grazing all contribute to lower water levels in the Basin and threaten the presence of deep pools essential for spring Chinook. Spring Chinook are also more sensitive to high temperatures than fall Chinook (Allen and Hassler 1986).

According to the National Research Council (2004), Migrating adults also need dissolved oxygen levels above five mg/l, deep water (deeper than 24 cm), breaks from high water velocity, and water turbidity below 4,000 ppm (NRC 2004).

Spawning gravel also must be free of excessive sediment such that water flow can bring dissolved oxygen to the eggs and newly hatched fish. With too much sediment, incubating eggs are smothered and reproductive success rate declines significantly. In a study on the Shasta River (Ricker 1997), six out of seven locations, had levels of fine sediment high enough to significantly reduce fry emergence rates and embryo survival. Logging, mining, and grazing increase sediment in Chinook spawning habitat in the Basin. Spawning occurs primarily in habitats with large cobbles loosely imbedded in gravel and with sufficient flows for subsurface infiltration to provide oxygen for developing embryos (Moyle et al. 2008). In a survey of Trinity River Chinook redds, Evenson (2001) found embryo burial depths averaged 22.5-30cm suggesting minimum depths of spawning gravels needed. Regardless of depth, the key to successful spawning is having adequate flows of water (Moyle et al. 2008).

Rearing

During rearing and migration, Chinook require certain temperatures, habitat diversity, and water quality characteristics.

After hatching, juvenile Chinook require rearing habitat before making their migration to the estuary and to the ocean. Ideal fry rearing temperature is estimated at 13ºC and temperatures above 17ºC are linked with increased stress, predation, and disease. High water temperatures can prevent smoltification, an essential process that prepares fish to leave freshwater habitat (McCullough 1999).

Stream temperature during migration is critical, as prolonged exposure to temperatures of 22-24ºC has resulted in high mortality for migrating smolts, and juveniles who transform into smolts above 18ºC may have low survival odds at sea (Baker et al. 1995, Myrick and Cech 2001).Vegetation provides relief from high temperatures, as well as shelter from predators (Moyle 2002). Logging, mining, and grazing all have reduced streamside vegetation in the Basin.

Habitat diversity is important for juvenile Chinook survival, as juveniles face predation by fish and invertebrates, as well as competition for rearing habitat from other salmonids (hatchery Chinook and Steelhead; Healey 1991, Kelsey et al. 2002). Chinook require the correct grades of gravel, the right depths and prevalence of deep pools as well as the existence of large woody debris and the right incidence of riffles (Montgomery et al. 1999). This allows for a variety of habitats which are required by Chinook at different life stages.

Chinook fry may compete for shallow water rearing habitat with hatchery fish and steelhead. Increased river flows mitigate this competition and help Chinook survival by increasing habitat on the river’s edge, where fry (under 50 mm) feed and hide from predators (NRC 2004).

As juvenile Chinook migrate down river, they prefer boulder and rubble substrate, low turbidity and water velocity slower than 30 cms^{-1} (Healey 1991). These conditions allow juveniles to use the faster-moving water in the center of the river for drift feeding, while resting in the slower areas (Trihey and Associates 1996). Smaller fish tend to stay in the slower-moving water near the banks of the river. High water turbidity threatens Chinook (Bash et al 2001) and in the Klamath Basin, logging and grazing both serve to increase turbidity.

Juvenile Chinook require high levels of dissolved oxygen (DO). Low DO levels decrease alevin and fry survival; decrease successful Chinook egg incubation rates; decrease the growth rate for surviving alevins, embryos, and fry; force alevins and juveniles to move to areas with higher DO; and negatively impact the swimming ability of juvenile Chinook (NCWQCB 2010). If DO levels average lower than 3-3.3 mg/L, 50% mortality of juvenile salmonids is likely, while in water above 20˚C, daily minimum DO levels of 2.6 mg/L are required to avoid 50% mortality (NCWQCB 2010). Factors in the Basin which contribute to sub-optimal DO levels include chemical pollution, logging, and dams.

Chinook salmon also require pH levels that are not too high. Even high pH levels which are not directly lethal to salmonids can cause severe harms to Upper Klamath Chinook (NCWQCB 2010), including decreased activity levels, increased stress responses, a decrease or cessation of feeding, and a loss of equilibrium (NCWQCB 2010). The Klamath River's pH in the summer often rises above 8.5, and sometimes reaches 9. At the Miller Island Boat Camp in 2008, the river's pH in early July, measured daily, had several consecutive days with pH values ranging from 9.06-9.53 (USGS 2009, Appendix B). Few studies directly examine the effects of high pH values on Chinook salmon. However, rainbow trout are stressed by pH values above 9 and generally die if the pH value rises above 9.4 (NCWQCB 2010). Nutrient loading of stream systems including those caused by agricultural runoff can lead to higher pH in river systems (NCWQCB 2010).

Once juvenile Chinook reach the estuary, less developed fall-run fry remain and seek out the tidal channel where the banks are low, while larger spring run smolts prefer near shore areas near the mouth of the river (Healey 1991). Juveniles change location with the tide as the salinity of the water changes. Larger Chinook smolts seek out deeper pools to avoid light.

Ocean

Once Chinook enter the ocean, most reside at depths of 40-80 meters (Healey 1991). Some research suggests that spring Chinook migrate further offshore, while fall Chinook tend to stay near the shore and close to their river (Allen and Hassler 1986). In the marine environment, Chinook salmon require nutrient-rich, cold waters associated with high productivity and higher rates of salmonid survival. Warm ocean regimes are characterized by lower ocean productivity which can affect salmon by limiting the availability of nutrients regulating the food supply and increasing the competition for food. Climate and atmospheric conditions can affect these conditions (NMFS 1998). In order to survive in the marine environment, Chinook salmon also require favorable predator distribution and abundance. This can be affected by a variety of factors including large scale weather patterns such as El Niño. NMFS (1998) cites several studies which indicate associations between salmon survival during the first few months at sea and factors such as sea surface temperature and salinity.

6. **FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE**

Discuss the basis for the threats to the species or subspecies, or to each population, occurrence or portion of range (as appropriate) due to one or more of the following factors:

(1) present or threatened modification or destruction of its habitat;

Dams

Dams in the Klamath Basin have destroyed Chinook habitat and forced modifications to the UKTR Chinook's range. Most fisheries biologists rate dams as being a "high" threat to both spring and fall Klamath Chinook salmon (NMFS 2009, J. Katz, pers. comm. 2010). The sequestration of habitat behind dams has acted as a major limiting factor to Klamath Basin Chinook populations, especially spring-run Chinook and the presence of these dams has likely inhibited recovery in years when conditions would otherwise have permitted it. In addition, dams affect the quality of habitat downstream by preventing spawning gravel from traveling downstream (Moyle et al. 2008), releasing limited, warm, and sometimes toxic water, and dictating unnatural stream morphology or structure.

Dams have been a barrier for Upper Klamath Chinook since 1912, when construction of Copco 1 Dam began (Hamilton 2016), closely followed by Copco 2 Dam in 1925. Iron Gate Dam represents the current extent of upstream migration for Chinook on the Klamath River. It was built in 1962 to produce hydroelectric power as well as to reregulate the wildly varying flows released by the Copco 1 and 2 Dams. In 1963, Lewiston Dam was built and became the current upstream limit to Chinook migration in the Trinity River.

UKTR spring Chinook have been particularly affected by dams, as they spawned largely in areas that are now unavailable (Moyle et al. 2008). Above Iron Gate Dam, there are approximately 970 km of blocked Chinook habitat (Hamilton et al. 2005). The construction of Dwinnell Dam in 1926 on the Shasta River blocked habitat that led to the disappearance of the Shasta River spring run (NRC 2004). Half of the available spawning habitat in the Trinity River Basin was blocked by Lewiston Dam (Myers et al. 1998). These restrictions to Chinook spawning range have been widely implicated in the decline of Upper Klamath Chinook populations, particularly spring run populations, throughout the Klamath Basin. Another result of limits to upstream habitat has been the introgression of the spring and fall runs, leading to a decline in genetic variability and further threatening the long-term viability of the ESU (Moyle et al. 2008).

Dams also contribute to a reduction in spawning gravel. Gravel can be caught in reservoirs behind dams and is unable to travel downstream to spawning habitat. Limited access to spawning gravel has been reported to affect spawning prevalence in both the Shasta and Klamath Rivers (Kondolf 2000).

Dams have negative effects on downstream water quality. The water which is held behind dams is both stagnant and warm and serves to dramatically increase the prevalence of Harmful Algal Blooms (HABs) in reservoirs and downstream (Humborg et al. 2000, Anderson et al. 2002). Dams also decrease levels of dissolved silicon in the water, leading to changes and imbalances in downstream phytoplankton communities and increased human water use causes raised levels of nitrogen and phosphorous in reservoirs, all contributing to the prevalence and severity of HABs (Humborg et al. 2000, Anderson et al. 2002). HABs have been noted at abnormally high levels in both the Copco and the Iron Gate Reservoirs, such that the EPA demanded that California include microcystin toxin (released by HABs) as a cause of impairment in the Klamath River (EPA 2008). In 2006, microcystin toxins were measured in those reservoirs at 600 times the World Health Organization’s recommended levels (EPA 2008). Higher levels of algal productivity also leads to increased decomposition, which in turn leads to lower levels of dissolved oxygen in the water (Correll 1998). In addition to causing HABs, reservoirs are also environments that harbor high levels of certain parasites affecting Upper Klamath Chinook (Bartholomew et al. 2007), and Chinook downstream from dams have been observed to have heightened infection rates from those parasites due to higher exposure doses (Bartholomew et al. 2007).

Channel morphology is altered by dams as well. Chinook salmon need a variety of different stream features to host a complicated interplay of biological and physical processes; they need the correct grades of gravel, the right depths and prevalence of deep pools, the existence of large woody debris, and the right incidence of riffles (Montgomery et al. 1997). Dams alter stream morphologies greatly, leading to a much narrower channel and a less complicated environment (Van Steeter & Pitlick 1998), which in turn leads to lower Chinook salmon populations (Montgomery et al. 1997). Meanwhile, reservoir morphology contributes to lower levels of dissolved oxygen (Cole & Hannan 1990). Low levels of dissolved oxygen have been noted on the Shasta River below the Dwinnell Dam, (CRWQCB 1993). The presence of dissolved oxygen is critical for the health of downstream fish populations. The particular effects of dissolved oxygen on Upper Klamath Chinook include serious problems with egg and embryo survival, as well as changes in behavior.

Dams have had a major impact on Upper Klamath Chinook populations. They have blocked off habitat throughout the Basin, prevented essential spawning gravel from traveling downstream, damaged water quality and changed channel morphologies of Klamath Basin streams. Dams both decrease available habitat and add to significant existing water quality problems in the Klamath.

Water withdrawals

Water withdrawals also pose a significant risk to UKTR Spring Chinook (NMFS 2009, J. Katz, pers. comm. 2010). Since 1906 and the start of the Bureau of Reclamation's Klamath Project, a large portion of Klamath Basin surface and ground water has been withdrawn for agricultural uses. For decades this was done without considering the effects on anadromous fish in the Basin, and on Upper Klamath Chinook in particular (Foster 2002, Hecht & Kamman 1996). Agricultural water withdrawals have had a major impact on Upper Klamath Chinook populations, as resulting low flows and high temperatures cause stress and direct mortality of fish, contribute to disease prevalence and severity, and decrease Chinook egg survival.

The Project was constructed in order to reshape the dry hills of the Klamath Basin into agricultural land (Foster 2002), and wildlife have long played an inferior role in shaping land use policies in the Basin (Foster 2002). Historically, the Klamath Basin hosted a vast system of wetlands, shallow lakes, and marshes that effectively stored water during the wet season and released water in the main stem rivers during dry summer months, providing cool, clean water to fish and wildlife (Foster 2002). Today, over 80% of these wetlands have been drained in the interest of agriculture (Doremus & Tarlock 2003), eliminating key natural water storage resources in the basin. Without increased water storage and with intense competing uses, water withdrawals for agricultural use are, in their ongoing inefficient form, incompatible with the survival of Upper Klamath Chinook (Doremus & Tarlock 2003).

Water withdrawals in the Basin have increased steadily since they began and threaten fish survival in the Basin. In the Trinity River, from 1964-2004, 75-90% of the River's water was rerouted to the Central Valley for agricultural purposes (Moyle et al. 2008). Diversions into the A Canal (the primary diversion channel to the Klamath Project) increased from approximately 190,000 acre feet in 1929 to 290,000 acre feet in 1989 (Hecht & Kamman 1996), and 350,000 in 2010 (NMFS 2010). Under the pending Klamath Basin Restoration Agreement, farmers would be guaranteed levels close to the current average and significantly higher than historical rates, at 330,000 acre-feet (KBRA 2010), an amount incompatible with Chinook recovery and survival. The 2010 NMFS Biological Opinion on the Klamath Project stated that the lowered summer flows are undoubtedly connected to decreasing coho populations (NMFS 2010). Because Upper Klamath Chinook live in the same habitat as the species addressed in the Biological Opinion, the effects of withdrawals may be extended to Chinook salmon as well (NRC 2004). Since the listing of coho, stream flows in the Klamath Basin increased only briefly in 2001, before political pressure from irrigators forced the Bureau of Reclamation to resume irrigation in 2002 (Doremus & Tarlock 2003). The Ninth Circuit decision revising the NMFS ruling has supported resident coho, but has not resolved the Basin's overall crisis (NMFS 2009).

The Shasta and the Scott rivers are currently all but uninhabitable for Upper Klamath Chinook (Chandler 2009). In the summers of 2008 and 2009, both the Scott and Shasta rivers were at their lowest levels since flow recording began, with the Scott River's flow falling to two cfs on August 14th 2009, despite the fact that precipitation that year was at 77%. The Shasta River shared the Scott's predicament, with its flows almost reaching six cfs on October 11, 2008, when fall Chinook normally spawn.

Water withdrawals have altered the natural hydrograph of the river and increased the seasonal variability by decreasing summer flows, which are most essential for the fall run of Upper Klamath Chinook (Hecht & Kamman 1996). The Upper Klamath Basin, with its porous volcanic rock and numerous wetlands and lakes, was historically a natural storage facility, contributing a large proportion of stream flows during drought years as well as late-summer months (Hecht & Kamman 1996), with the snowpack contributing to flows mostly during the spring and summer (Hecht & Kamman 1996). One major effect of the combination of water withdrawals and dams is that the snowmelt peak that increased flows in spring and early summer is greatly reduced (Hecht & Kamman 1996). In 2010, the NMFS Biological Opinion stated that the altered hydrograph from the Klamath Project was harming coho (NMFS 2010). Chinook fry require water flow rates above certain levels (Allen 1986), and it is likely that this seasonal reduction in water flows arrives to the detriment of Upper Klamath Chinook populations.

High temperatures caused by water withdrawals and resulting low flows are a serious threat to Upper Klamath Chinook, causing increased stress levels and mortality. The temperatures in three Klamath Basin tributaries were measured every day in August and September of 2002. Average temperatures during September 2002, before the fish kill, ranged from 23°C to 17°C (Guillen 2003). Research shows that water temperatures in the Shasta exceeded 21°C on a daily basis for the entire summer season and through September during both 2002 and 2003 (Flint et al. 2005). Maximum temperatures in the Shasta reached nearly 30°C in mid-July, far above temperatures which can lead to Chinook stress and mortality (Flint et al. 2005). Increased water temperatures due to low instream flows have affected spring Chinook in particular (NRC 2004). Spring Chinook generally need temperatures below 16˚C due to disease prevalence and loss of egg viability; but the deep pools holding spring Chinook in the Salmon river have temperatures often exceeding 20˚C (NRC 2004).

Low flows and warm temperatures caused by water withdrawals also inhibit migration and cause crowding which create ideal conditions for disease outbreaks (McCullough 1999, NRC 2004). This was demonstrated during the Klamath Basin fish kill of 2002. Withdrawals above Iron Gate Dam in September of this year, immediately before the fish kill, reduced flows from the dam from an estimated 1441-1470 cfs (cubic feet per second) to 759 cfs (Guillen 2003) and these low flows were implicated as a cause for the rapid spread of Ich and Columnaris.

Other diseases thrive under warmer conditions as well. Many diseases that affect the Upper Klamath Chinook population are dormant at temperatures below 15.6°C (McCullough 1999). Increased levels of *Ceratonova shasta* infection in Klamath and Trinity Chinook populations Chinook were noted in 2009, with especially high rates immediately below the Iron Gate Dam where high temperatures are most apparent, upstream of major tributaries (True et al. 2010). This effect is no doubt also partly due to the fact that the stagnant, warm waters of reservoirs are ideal environments for *C. shasta* and their polychaete hosts (True et al. 2010).

Water withdrawals which lead to lower flows and warmer stream temperatures drastically decrease Chinook egg survival (McCullough 1999). The EPA has determined that temperatures above 13°C are unsuitable for Chinook spawning (EPA 2003). Temperatures above 15.6°C result in near total mortality for Chinook eggs (McCullough 1999). Higher water temperatures also result in smaller alevins and fry, as well as higher rates of alevin abnormality (McCullough 1999). The increased temperatures in the Klamath River in September and October have narrowed the available incubation period for Chinook eggs (Hecht & Kamman 1996) and may limit the species' overall reproductive success.

Water withdrawals are prevalent throughout the region and have caused dramatic changes to Upper Klamath Chinook habitat. This represents a persistent and ongoing threat to the long-term survival of this species in the Klamath Basin.

Logging

Historically, the Klamath Basin was heavily forested, with forest covering approximately 80% of the Upper Klamath Lake watershed alone (NRC 2004), providing stability and shade for streams. Logging in the Klamath Basin, after its beginning in the 1850s, expanded rapidly starting in the 1910s (NRC 2004); 120 million board feet of timber were logged in the upper Basin in 1920, and by 1941 timber harvesting increased to 808.6 million board feet in the upper Basin alone (NRC 2004). As of 2004, approximately 400 million board feet of timber were logged in the upper Basin annually (NRC 2004). Logging also involves the construction of road systems. In the Scott River watershed alone, more than 288 miles of logging roads were constructed as of 2004, as well as more than 191 miles of skid trails (NRC 2004). Logging is a particularly high threat for spring Chinook (J. Katz pers. comm. 2010). Logging poses a significant threat to Chinook habitat by increasing stream erosion, sedimentation and turbidity, blocking Chinook access to habitat, decreasing riparian shade, decreasing the presence of large woody debris, and leading to complications with wild fire.

Erosion and the resulting sedimentation of streams is likely the largest threat to Upper Klamath Chinook caused by deforestation. The Klamath Basin's geomorphology is particularly vulnerable to erosion, because of the steep and unstable slopes of the region (Moyle et al. 2008), and the particularly erosive soils that underlie much of the Basin, particularly in the Scott and Trinity River watersheds (NRC 2004). In the Upper Klamath Lake watershed, more than 73% of forest land is subject to severe erosion caused by logging (NRC 2004). Logging and associated road construction has long-lasting effects on the sedimentation and turbidity of nearby streams (Klein et al. 2008). Indeed, the sediment contribution to streams by roads is often greater than that from all other land-use activities combined (NMFS 1996). The construction of roads and skidtrails in the lower Klamath Basin has been a "major source" of fine sediment in the Basin (NRC 2004). One study found that in the Scott River, average erosion for a road surface alone is 11 tons per acre; including the entire road prism, this figure rises to 149 tons per acre (Sommerstram et al. 1990). Skid trails, created during logging projects, are even more erosive, with skid-trails in the Scott averaging an annual 239 tons of soil loss per acre (Sommerstram et al. 1990). It is estimated that 10%-55% of the eroded soil makes it into the Scott River as sediment (Sommerstram et al. 1990).

Furthermore, sediment is added to streams in logged areas long after the initial logging project has been completed (Klein et al. 2008). Indeed, the timber harvest rate seems to be the biggest factor contributing to high levels of turbidity measured in a stream, with an unlogged area made up of highly erosive geology, near the Klamath Basin, showing low turbidity levels (Klein et al. 2008), while logged streams nearby, with less erosive geology, showed higher turbidity levels (Klein et al. 2008).

Increased turbidity and sedimentation create adverse conditions for Chinook. The particular effects of fine sediment on Chinook and its habitat include lowered levels of dissolved oxygen, suffocation of eggs and alevins, and lowered ecosystem productivity, which results in lower levels of food available for juveniles (Cordone & Kelley 1961).

Logging has resulted in blocked and destroyed habitat for Chinook in the Basin. Spawning habitat has been restricted in the Klamath Basin during periods of low flows by aggradations due to erosion (USBR 2001) as well as through the creation of impassible barriers such as culverts (Hoffman & Dunham 2007). Shallow landslides caused by logging and road construction scour streambeds and decrease stream complexity, destroying Upper Klamath Chinook habitat (Dietrich & Real de Asua 1998). The incidence of shallow landslides is greatly increased by the presence of logging (Dietrich & Real de Asua 1998). Habitat is also undermined as sediment leads to fewer deep pools (Quigley & Arbelbide 1997).

Logging and associated roads have also been shown to lead to decreases in riparian vegetation (Quigley & Arbelbide 1997) which leads to increased stream temperatures (Bartholow 2000). Indeed, it is likely that the largest contribution to stream temperatures in most rivers is linked to decreased riparian vegetation (Bartholow 2000). The Shasta River, due to its structure–a relatively narrow channel–is particularly vulnerable to the lack of riparian shade (NRC 2004), and it is estimated that mature riparian vegetation would lower average maximum temperatures from 31.2°C to 24.2°C (NRC 2004).

Another effect of logging is reduced presence of large woody debris (LWD) in streams (Moyle et al. 2008). LWD is an essential element of Upper Klamath Chinook habitat (Rinella et al. 2009), as it helps form and maintain the deep pools necessary for juvenile Chinook, while aiding the recruitment of spawning gravel and creating cover for Chinook from predation (Rinella et al. 2009). LWD also contributes to stream productivity by adding habitat and food for the macrobenthic invertebrates that serve as food for juvenile Chinook (Rinella et al. 2009). Studies have shown that streams with LWD tend to harbor more salmonids, while LWD removal has been shown to lead to salmonid population decline (Rinella et al. 2009). In the Klamath Basin, logging on the Shasta River watershed has resulted in particularly low levels of LWD (NRC 2004). However, the 2010 coho Biological Opinion has found that lack of LWD is an issue in a “variety” of northern California and southern Oregon coho streams, many of which are also used by Upper Klamath Chinook (NMFS 2010)

As logging increases, so does the prevalence of wildfires (NRC 2004). The logging of old, large trees, especially when combined with fire suppression, results in more dense undergrowth, susceptible to fires (NRC 2004). Loggers often leave behind unsellable branches and detritus, which increase fire prevalence and severity (Donato et al. 2006). Since the early 1900s, the Salmon River, the last remaining viable habitat for Upper Klamath spring Chinook, has been battered by damaging crown fires, and now more than 50% of the Basin has burned (NRC 2004) with devastating effects. The extent and severity of large scale fires in the Salmon River watershed has increased over time, largely as the result of fire suppression efforts over the past century and an overall increase in heating and drying trends. In less than 15 years, from 2000 to 2014, over 43% of the Salmon River watershed has burned in mostly large fire events, with some areas burning multiple times at high severity (SRRC 2018).Short-term effects of wildfires on stream habitat include direct increases in stream temperatures, changes in stream pH, and the addition of toxic chemicals to the water (Engstrom 2010). Longer term effects include chronic and pulse erosion, channel reconfiguration, decreases in quality and quantity of large woody debris, reductions in streamside vegetation, and increases in both turbidity and stream sedimentation (Engstrom 2010).

After a fire has swept through the forest, permits are often granted for “post fire” or “salvage” logging, in an attempt to reduce future fires by taking out dead trees (Donato et al. 2006). However, there is evidence that post fire logging actually increases the risk of future fires (Donato et al. 2006), while also significantly reducing the regeneration rate of the forest (Donato et al. 2006). Studies on post fire logging after the Biscuit fire in the nearby Siskiyou National Forest (Donato et al. 2006, Thompson et al. 2007), found increased fire severity and decreased levels of regeneration in areas that have been “salvage” logged in comparison to areas left intact. Both scenarios have adverse effects on sediment levels in rivers as well as water temperatures, driving both effects upwards and consequently increasing the harm done to Upper Klamath Chinook populations.

Indirectly, logging roads also lead to habitat damage by providing access for forms of recreation that are harmful for Chinook (Quigley & Arbelbide 1997).

A significant portion of land in the Klamath River Basin remains open to logging. Land ownership in the Basin is 35 percent private, which is largely open to logging and urban and agriculture development with few protections in place for Chinook salmon or their habitat. In addition, there are over 700,000 acres, or roughly 16% of the basin, of Bureau of Land Management and the U.S. Forest Service lands that are designated as matrix lands under the Northwest Forest Plan, which are largely open to logging. See Table 3 for additional land ownership information:

Table 3.

Land Ownership in the Klamath River Basin Downstream from Dams			
Agency	Land Use Allocation	Acres	% Watershed
U.S. Forest Service		2,772,123	62.66
	Adaptive Management Area	335,264	
	Adaptive Management Reserve	23	
	Administratively Withdrawn	80,482	
	Congressionally Reserved	732,577	
	Late Successional Reserve	825,339	
	Late Successional Reserve (Murrelet)	694	
	Late Successional Reserve (Owl)	15,849	
	Matrix	640,646	
	Riparian Reserve	132,274	
Private		1,533,024	34.65
U.S. Bureau of Land Management		98,179	2.22
	Adaptive Management Area	1,807	
	Administratively Withdrawn	6,104	
	Congressionally Reserved	4,462	
	Late Successional Reserve	4,166	
	Late Successional Reserve (Owl)	341	
	Matrix	66,191	
	Riparian Reserve	13,666	
Other*		20,860	0.47
Total Watershed Area		4,424,186	

*Other land owners include California Department of Fish and Game, California Department of Forestry and Fire Protection, California Department of Parks and Recreation, California State Lands Commission, City of Etna, Happy Camp Community Services District, Lake Shastina Community Services District, Other State Land, The Nature Conservancy, County of Trinity, U.S. Bureau of Reclamation, U.S. National Park Service, City of Weed, City of Yreka, and Weaverville-Douglas City Recreation District.

Logging remains a serious issue for Upper Klamath Chinook. Despite the legacy of sediment-choked streams, dangerously warm waters, and fire-vulnerable forests left by 100 years of heavy logging, forest management has continued in a destructive and unsustainable direction (NRC 2004). In combination with elements like water withdrawals and mining, what once might have been a mere irritant to Upper Klamath Chinook populations is further aggravating existing and serious threats to survival.

Mining

Historic mining in the Klamath Basin has caused damage to Upper Klamath Chinook habitat through the rearrangement of the landscape, increased sediment and mercury pollution.These legacy affects persist to this day in the form of greatly degraded habitat that is resistant to recovery through natural processes. More recently, suction dredge mining has continued to affect Chinook in the Basin through the entrainment of fish and their food, increased erosion and the associated complications with sediment and turbidity. Also, suction dredge mining causes the destabilization of spawning and downstream habitat.

Beginning in the 1850s, miners arrived in the Basin in great numbers and major human-caused changes to Klamath Basin geography and ecology became widespread (NRC 2004). During the midnineteenth century, gold rush miners used environmentally harmful methods of extracting gold from streams without regard for consequences (NRC 2004). One method, implemented in 1853, involved using high pressure water to blast away dirt and uncover placer deposits (NRC 2004). Many creeks were diverted into reservoirs for this purpose, and the jets of water unleashed sometimes washed away entire hillsides (NRC 2004). Much of the landscape in the Klamath Basin has been rearranged by this form of mining (NRC 2004). In California, before a court order mitigated some of the most harmful practices in 1884, hydraulic miners washed an estimated 1.6 x 10^9 yd^3 of sediment into the streams, hard rock miners created 3 x 10^7 yd^3 of mine tailings, and dredge miners left behind 4 x 10^9 yd^3 of debris, largely in the Klamath Basin (NRC 2004). Using the Salmon River sub-basin as an example, the Salmon River Floodplain Habitat Enhancement and Mine Tailing Remediation Project, Phase 1: Technical Analysis of Opportunities and Constraints, summarizes the legacy mining effects as follows (Stillwater, 2018):

> One of the most important factors leading to the decline and continued low abundance of anadromous salmonids in the Salmon River, and in particular spring-run Chinook, is the legacy effect of historical placer mining on channel and floodplain habitat conditions throughout the mainstem and larger tributary reaches (Stumpf 1979, SRRC 2017). Hydraulic and dredge placer mining in the Salmon River between about 1870 and 1950 led to profound and lasting changes, eroding over 1,859 acres adjacent to the mainstem and larger tributary channels and delivering an estimated 20.3 million cubic yards of sediment to the river (Hawthorne 2017, de la Fuente and Haessig 1993). Placer mining denuded floodplains and adjacent river terraces and hillslopes, reduced riparian shade cover, and exposed the stream channel and surrounding areas to increased solar radiation.
>
> Delivery of hydraulic mine debris resulted in as much as 5 meters of channel aggradation, on average, throughout the predominantly alluvial reaches within the Project area. Aggradation by hydraulically mined sediment widened and shallowed alluvial reaches, filled pools, reduced the complexity and connectivity of floodplain habitats, and led to coarsening and armoring of the channel bed. Coarse sediment stored in the bankfull channel, denuded floodplains, and mine tailings on terraces along the river corridor continues to prevent riparian vegetation establishment, and due to the increased exposure to solar radiation and thermal mass, creates a significant heating effect. These impacts significantly reduce the amount and quality of spawning, oversummering, and over-wintering habitat and decrease the cumulative channel length that remains thermally suitable for salmonids during the summer, thereby constraining population productivity and increasing extinction risk. These legacy impacts to the channel and floodplain inhibit natural recovery and require intervention to recover within human and salmon population time scales.

Historically, gold mining involved the use of mercury, large quantities of which was released back into the Klamath River (NRC 2004). It is estimated that with hydraulic mining, approximately one pound of mercury was released for every three to four ounces of gold recovered (NRC 2004). Much of that mercury remains in Klamath Basin soils and sediments, affecting Upper Klamath Chinook through leaching, as well as any animal or human that consumes them (NRC 2004). Even in the 19th century, the California government acknowledged the effects of mining on Klamath Basin salmon, and in 1852, it enacted its first salmon statute, though this piece of legislation had little practical effect (NRC 2004).

Much of the mining activity in the 19th century still affects whole streams in the Klamath Basin, and some areas, such as the Scott River, have been permanently damaged (Moyle et al. 2008). Even the Salmon River, now the last bastion for UKTR Spring Chinook, has approximately 20million cubic yards of sediment, unleashed by mining between 1870 and 1950, slowly making its way downstream (Hawthorne 2017, de la Fuente and Haessig 1993). This sediment harms juvenile habitat, fills in the deep pools needed for adult Chinook, and degrades spawning habitat by eliminating the correct grade of gravel (Moyle et al. 2008). According to the findings of a recent and extensive assessment of mining effects on floodplains and anadromous fish habitat in the Salmon River, "Channel and floodplain aggradation resulting from historical hydraulic mining widened and shallowed alluvial reaches, filled pools, reduced the complexity and connectivity of floodplain habitats, and led to coarsening and armoring of the channel bed. Coarse sediment stored in the river channel, denuded floodplains, and mine tailings along the river corridor continue to create a significant heating effect. These legacy impacts to the channel and floodplain inhibit natural recovery and require intervention to recover within human and salmon population time scales" (Stillwater 2018). Old gold mining practices have also left their mark on the Trinity River, an area of particular concern for mercury contamination (Alpers et al. 2005).

More recently, suction dredge mining has been used for extracting gold from the Basin. Dredge mining has been operating in California continuously since the invention of the suction dredge in the 1960s (CDFG 2009), and Upper Klamath Chinook populations have been directly impacted by this activity. Effects of suction dredge mining include the entrainment of juvenile fish and eggs (Harvey & Lisle 1998), as well as the entrainment of macrobenthic invertebrates that serve as food for juvenile Chinook (Moyle et al. 2008). Apart from entrainment of macrobenthic invertebrates that serve as an important food source for juveniles, the exposure of new substrate and the deposition of sediment in the streams causes localized reductions in both macrobenthic invertebrate presence and diversity (Harvey & Lisle 1998).

Dredging has long-term erosive consequences, increasing the sediment load of streams and altering habitat by filling deep pools and eroding stream banks that formerly served as shelter for the Chinook. Effects can last for years after the dredgers have left (Harvey & Lisle 1998). Similarly, dredging of riffle crests can cause them to erode, potentially destabilizing spawning habitats, filling deep holes, and destabilizing downstream reaches (Harvey & Lisle 1998). Furthermore, dredge mining that has disturbed riffle crest tends to channel the streamwater towards a stream bank, increasing streambank erosion (Harvey & Lisle 1998).

Suction dredge mining also stirs up sediment, adding to a stream's turbidity (Harvey & Lisle 1998). Increased turbidity resulting from dredge mining can have negative effects on Upper Klamath Chinook, particularly juveniles. Increased levels of suspended solids in the water seem to result in increased foraging time by juvenile Chinook, as it reduces their reactive distance and prey capture success rate (Harvey & Lisle 1998). Higher levels of suspended sediment can also reduce primary production in a stream, as the sediment blocks off light needed for photosynthesis (Henley et al. 2000). This limits food available for organisms at higher trophic levels (Henley et al. 2000), including juvenile Chinook.

Suction dredge mining can also increase deposition of fine sediment downstream (Harvey & Lisle 1998), reducing both the benthic invertebrate populations that serve as food for Chinook (Harvey & Lisle 1998), and the availability of habitat for alevins inhabiting the benthic zone (Harvey & Lisle 1998). Increased fine sediment deposition also reduces dissolved oxygen levels by filling interstices between gravel and reducing water circulation in the hyporheic zone (Henley et al. 2000). The hyporheic zone is the zone of gravel and sediment that composes the streambed, where groundwater and surface water interact (Findlay 1995), and where Upper Klamath Chinook deposit their eggs. Increased fine sediment deposition due to mining is of particular concern in the Trinity and Salmon rivers (NRC 2004).

Suction dredge mining leads to the destruction of Chinook redds (Harvey & Lisle 1999). Miners dredge up and then deposit gravel that is seemingly the perfect size and density for Chinook redds, attracting spawning Chinook. The tailings placed back into the stream are unsupported however, and during the high flow period in winter after the Chinook have used the sediment for spawning, the gravel is swept downstream, killing any eggs present (Harvey & Lisle 1999). The same instability kills Chinook alevins inhabiting the gravel substrate (Harvey & Lisle 1998).

Mine tailings from suction dredge mining also reduce deep pools (Harvey & Lisle 1999) that are essential habitat for both juvenile and adult Chinook. The presence of unstable mine tailings used by Chinook as spawning grounds has been noted throughout the Klamath, Salmon, and Scott rivers and their tributaries (Moyle et al. 2008).

Other general effects include the loss of channel complexity, the loss of pool habitat, and the loss of effective large woody debris (NMFS 1998). Finally, the constant noise and turbidity caused by suction dredge mining raises the stress of Upper Klamath Chinook, increasing the possibility of premature death (Moyle et al. 2008).

Suction dredge mining currently poses a threat to Upper Klamath Chinook. Recently, California recognized the threat posed to salmonids by suction dredge mining and temporarily banned it in California streams, pending environmental review. The long-term damage has already occurred to Upper Klamath Chinook habitat, and with the very limited budget California can put towards enforcing the ban, many suction dredge miners are able to continue their activities with impunity. Mining has historically caused major damage to Chinook habitat in the Klamath Basin and remains a threat to their continued existence.

Chemicals

Land use in the Klamath Basin has resulted in the contamination of the region's waters by a variety of chemicals including pesticides, herbicides, and insecticides. Basin agricultural lands discharge chemical and fertilizer-contaminated wastewater, and municipal wastewater also enters the system through the Lost River. Combined, these wastewater discharges result in harmful algal blooms, higher aquatic pH levels, lower levels of dissolved oxygen, and high concentrations of ammonia (NCWQCB 2010), all of which are destructive for Chinook populations (Moyle et al. 2008).

Pesticides, insecticides, and herbicides have been used in the Klamath Basin for at least 60 years (Dileanis et al. 1996).This includes the heavy use of dangerous organochlorine pesticides such as DDT in the 1950s and 1960s, which are found in Tule Lake and elsewhere in the Basin (Dileanis et al. 1996). In the early 1990s, 16 pesticides were reported in the waters of Tule Lake Refuge, with higher concentrations measured near agricultural drains (Dileanis et al. 1996). Between 1997 and 2001, approximately 27,000 pounds of the active ingredients of four forestry herbicides were used in the Klamath Basin. In 2002, research determined that some of the forestry herbicides were drifting into waterways (Wofford et al. 2003). So far in 2010, pesticide use proposals for 81 pesticides (including those known to be dangerous to wildlife) have been granted for lease lands within the Tule Lake and Lower Klamath National Wildlife Refuges (USBR 2010).

In long term studies, USGS (2009) found high levels of a variety of pollutants especially in the 20 miles between Link River and Keno Dam. Given the high levels of toxicity, the State of Oregon classifies this 20 mile reach as "water quality limited," as required by Section 303(d) under the Clean Water Act (USGS 2009). Water quality in this region affects the quality of the entire main stem of the Klamath River. (Sullivan et al. 2010).

In 2008 the EPA issued a Biological Opinion on "the effects of the U.S. Environmental Protection Agency's (EPA) proposed registration of pesticide products containing the active ingredients chlorpyrifos, diazinon, and malathion on endangered species, threatened species, and critical habitat that has been designated for those species" (NMFS 2008). The Opinion assesses the effects of these pesticides on 28 listed Pacific salmonids and determines that the continued use of these chemicals is likely to jeopardize the continued existence of 27 listed Pacific salmonids and to destroy or adversely modify critical habitat for 25 of 26 listed Pacific salmonids, with critical habitat, including the Klamath Basin's Southern Oregon/Northern California Coast Coho (NMFS 2008). The population-level consequences of pesticide use discussed in this report included impaired swimming and olfactory-mediated behaviors, starvation during a critical life stage transition, death of returning adults, additive toxicity, and synergistic toxicity. Upper Klamath Chinook also negatively affected by these pesticides.

Diazinon, an organophosphate insecticide commonly used for general pest control, has been found to affect the olfactory nervous system of Chinook (Scholz et al. 2000). As Chinook depend largely on their olfactory system for homing, reproductive behavior, and pheromone activated anti-predator behavior, disruption of the sense of smell has wide-ranging negative effects on Chinook populations (Scholz et al. 2000). This disruption likely increases occurrence of Chinook "straying" (spawning fish returning to nontraditional spawning grounds), with results ranging from hybridization between hatchery and wild fish (Scholz et al. 2000) to lower densities of spawning Chinook in streams, leading to reproductive failure. Diazinon also negatively affects anti-predator behavior and the reproductive behavior of male Chinook (Scholz et al. 2000).

Other chemicals such as carbaryl, the third most commonly used insecticide in the United States, have been shown to neurologically affect salmonids (Labenia et al. 2007). Furthermore, pesticides seem to act synergistically, such that sub-lethal doses of two different pesticides may have effects greater than when they are encountered individually (Laetz et al. 2009). In one study, every pesticide tested acted synergistically with every other pesticide, and malathion and chlorpyrifos proved to be a particularly harmful combination (Laetz et al. 2009); both of those pesticides have been approved for use on Klamath Basin National Wildlife Refuge lease lands (USBR 2010), and are likely used to a much greater extent throughout the Klamath Irrigation Project.

Fertilizer and organic nutrients from agriculture and municipal wastewater present a serious threat (USGS 2009) by fueling algal blooms, depleting dissolved oxygen levels, and elevating pH levels (Smith et al. 1999). Algal blooms and subsequent fish die-offs are also linked to the presence of ammonia in the water (Rykbost & Charlton 2001). In the United States, eutrophication caused by agricultural runoff is the nation's largest water pollution problem (Smith et al. 1999) and the Klamath Basin is no exception. The Klamath Straits Drain, a concrete canal which collects the upper Basin's agricultural, refuge, and municipal wastewater and discharges it into the main stem of the Klamath River, has been designated "water quality limited" on Oregon's 303(d) list for dissolved oxygen and ammonia levels year round and for the water's pH and chlorophyll concentrations during the summer (USGS 2009). Discharge from the Klamath Straits Drain is impacted by high concentrations of total phosphates, biochemical oxygen demand, total solids, and ammonia and nitrate nitrogen throughout the year (ODEQ 1995).

Lowered dissolved oxygen (DO) levels due to impaired water quality as a result of agricultural and/or municipal inputs inflict harm on Upper Klamath Chinook (NCWQCB 2010). During July of 2008, the levels of DO measured above the Keno Dam were far below levels recommended for salmonids; if DO levels average lower than 3-3.3 mg/L, 50% mortality of juvenile salmonids is likely, while in water above 20˚C, daily minimum DO levels of 2.6mg/L are required to avoid 50% mortality (NCWQCB 2010). However, in 2008 from mid-July to mid-September at the Keno Dam, DO levels repeatedly dropped below one mg/L (sometimes to as low as .38 mg/L), and rarely rose to three mg/L (USGS 2009, Appendix B).

Nutrient loading of stream systems can lead to higher pH in river systems (NCWQCB 2010). The effects of a high pH on Upper Klamath Chinook are exacerbated by high temperatures (NCWQCB 2010), which is already a major water quality problem in the Klamath Basin. Due to impaired water quality as a result of agricultural, municipal, and other inputs as discussed, the Klamath River's pH in the summer often rises above 8.5, and sometimes reaches 9. At the Miller Island Boat Camp in 2008, the river's pH in early July, measured daily, had several consecutive days with pH values ranging from 9.06-9.53 (USGS 2009, Appendix B). Few direct studies examine the effects of high pH values on Chinook but rainbow trout are stressed by pH values above 9 and generally die if the pH value rises above 9.4 (NCWQCB 2010).

Nutrient loading in the Klamath River can increase ammonia levels as higher concentrations of nitrogen enter the water (NCWQCB 2010). High nitrogen concentrations, a product of water runoff from fertilized agricultural fields, also increases the toxicity of the ammonia present, as higher pH levels result in most of the ammonia morphing into its deadlier, un-ionized form (NCWQCB 2010). Ammonia in the Klamath River has been noted at levels high enough to harm Chinook through a reduction in hatching success; reductions in growth rate and morphological development; and pathologic changes in tissues of gills, livers, and kidneys (NCWQCB 2010). Ammonia also reduces Chinook disease resistance and has been termed an exacerbating factor in Klamath River fish kills (NCWQCB 2010). The presence of high levels of un-ionized ammonia was noted in the Upper Klamath Lake in both 2007 and 2008 (USGS 2010).

In the Upper Klamath Lake, the combination of high pH (sometimes between 9 and 9.5 in late August) and temperatures (around 20˚C at the same time; USGS 2010) with high levels of ammonia can be dangerous. On August 25th, 2008, ammonia was measured at 0.933 mgN/L (USGS 2010), far above "acute" levels of ammonia for salmonids (0.885 mgN/L when the pH is 9; NCWQCB 2010). The USGS found that ammonia concentrations in the Klamath River actually increased in the downstream direction, with significantly higher levels found at the Keno Dam when compared to the Link River Dam (USGS 2009).

Agricultural and municipal wastewater delivered into the Klamath River is a severe threat to Chinook. Pesticides, even at sub-lethal doses, can combine to alter Chinook behavior, with major consequences for Chinook survival and reproduction. The eutrophication of traditional Upper Klamath Chinook habitat in the Klamath Basin results not only in levels of dissolved oxygen low enough to cause serious harm to Chinook populations, but also causes elevated pH levels, high concentrations of ammonia, and the presence of toxins produced by algal blooms.

Grazing

Grazing threatens UKTR Spring Chinook in the Basin because of the loss of riparian vegetation, loss of large woody debris, increased sediment in streams, the addition of excessive nutrients to streams, and lowered water tables.

Grazing in the Klamath Basin has occurred since the late 1800s. As early as 1880, overgrazed fields caused a disastrous winter for plant life resulting in the mass mortality of cattle across the Basin (NRC 2004). More widespread effects were quickly noted, as a geologist in the early 1900s found formerly flat streams cutting channels in the land, as run-off increased due to overgrazing (NRC 2004). In an effort to save the nascent Klamath cattle industry, government agents recommended that wetlands be drained and planted with hay to provide feed for cattle, and in the 1890s, ranchers obliged, draining wetlands along the borders of the Upper Klamath Lake to provide increased forage (NRC 2004). In addition to lost water storage capacity and lower water quality caused by wetland draining, the flood irrigation of pastures to create cattle feed as well as the switch to nonnative species of hay severed healthy riparian connections to the landscape (NRC 2004). Because cattle are attracted to riparian areas for grazing, damage caused by intense cattle presence is often concentrated in sensitive riparian areas (Belsky et al. 1999). The Scott and Trinity rivers have been degraded by under-regulated grazing and ranching, as have numerous small tributaries that contribute their flows to the Klamath River (NRC 2004). In the South Fork Trinity River, unsustainable grazing and farming practices, combined with large floods in 1964, have resulted in long-term loss of viability to salmon populations (NRC 2004). Populations in the South Fork Trinity River have made little progress recovering in the intervening decades (NRC 2004).

One major of effect of grazing in riparian habitats is the decrease riparian vegetation. Throughout the Klamath Basin, there is evidence that unfenced grazing results in the loss of vegetation through animal consumption and trampling (NRC 2004). Grazing is the primary contributor to the lack of riparian vegetation in the upper Shasta River (NRC 2004). Loss of riparian vegetation leads to increased stream temperatures as well as a decrease in the quality of Chinook habitat through the loss of large woody debris (NRC 2004) increased erosion and sedimentation, all of which have highly damaging consequences to Chinook salmon.

Cattle also cause increased levels of nutrients to be added to river systems. The effects of season-long grazing in the past in the Sprague River (a major tributary to the Upper Klamath Lake) have resulted in the Oregon Department of Environmental Quality labeling the Sprague River in the Upper Klamath Basin as one of the worst streams in Oregon for non point-source pollution (NRC 2004). Animal waste from grazing adds nutrients to water systems that can result in HABs (Belsky et al. 1999). The Sprague River is a contributor of extremely high levels of phosphorus due to poor land use practices (NRC 2004), including grazing. As phosphorus is the primary factor limiting algal blooms in freshwater systems (Anderson et al. 2002), its input is likely to be a major cause of HABs, which can have large effects on downstream Chinook populations, through the release of toxins (EPA 2008) and lowered levels of dissolved oxygen (Correll 1998).

Grazing has also been implicated in lowering water tables; as water flows downhill during floods, it is trapped by riparian plants, slowing flows and allowing the water to percolate through the sub-soil to become groundwater (Belsky et al. 1999). Extensive grazing, combined with groundwater withdrawals and sprinkler irrigation is a significant contributor to the problem of low water tables in the Scott River watershed (NRC 2004, Van Kirk & Naman 2008).The impact of low water tables in these critical Klamath River tributaries and throughout the upper Basin translates directly to limited river flows and impaired water quality for Upper Klamath Chinook downstream.

The legacy effects of grazing have permanently harmed Upper Klamath Chinook habitat and current ranching practices continue to impair the viability of populations through impacts on water quality. For every cattle herd grazing on upper Basin rangeland, water quality for downstream Upper Klamath Chinook populations is further degraded.

(2) overexploitation;

Commercial, recreational and tribal fishing have had a combined effect on Klamath River salmonids that have contributed to their decline since the 19th century (NMFS 2009; Snyder 1931). Both legal and illegal harvest combined pose a high threat for both spring and fall Upper Klamath Trinity River Chinook (J. Katz pers. comm. 2010). Harvest of Upper Klamath Chinook salmon has added to the decline of both the spring and fall runs and continues to threaten the long-term persistence of Chinook in the Basin (Moyle et al. 2008).

Moyle et al. (2008) identifies legal and illegal harvest as a major limiting factor affecting both spring and fall runs of Upper Klamath Chinook. Both illegal harvest of holding adults and legal, ocean and river harvests contribute to reduced spawning populations. Adults holding upstream in deep pools are especially vulnerable to illegal take; although these numbers are largely undocumented, it can be assumed that UKTR Spring Chinook holding in pools in the Klamath River and elsewhere in the Basin are affected by harvest from pools where they are holding prior to spawning. There is a general absence of UKTR Spring Chinook from populated areas in the Klamath, and in areas with easy access to humans, further suggesting that illegal harvest is occurring. The illegal removal of even a small number of UKTR Spring Chinook likely has an intense effect on spawning populations (Moyle et al. 2008).

Because managing agencies do not treat UKTR Spring Chinook differently from UKTR Fall Chinook, UKTR Spring Chinook are taken legally in commercial and sport fisheries (Moyle et al. 2008). Harvest rates are defined based on combined spring- and fall-run numbers of both hatchery and natural origins; therefore, the dwindling populations of spring-run Chinook, especially wild-spawning populations are particularly vulnerable to being overfished under current management (Bilby et al. 2005). In fact, current management actions neglect to protect spring-run Chinook even when protections have been put in place to restrict fall-run Chinook harvest, essentially increasing pressure on the much smaller and more imperiled populations of spring-run Chinook. For example, after the final stock projections developed by the Pacific Fishery Management Council for Klamath River fall-run Chinook (which included spring-run return numbers) were projected to be the lowest on record, "the Fish and Game Commission adopted regulations on April 13, 2017 for a full closure of the 2017 Klamath River Fall-Run Chinook Salmon fishery in the Klamath and Trinity rivers" (CDFW 2017). The regulations went into effect August 8, 2017, after the spring-run Chinook had already entered the Klamath Basin and its tributaries. Even though low spring-run Chinook return numbers were counted as part of these projections, they were not granted equal protections to fall-run Chinook, and the daily bag limits on the Klamath River remained the same for the period of time that they were present in the river before fall-run Chinook entered the basin. During this time period, the only allowable salmon sport fishing on the Klamath River was spring-run Chinook, effectively increasing the pressure on dwindling spring-run Chinook during this year with the lowest projected returns.

(5) disease; or

Several diseases affect the Upper Klamath Trinity River Chinook salmon and will likely continue to pose a threat to this ESU in the future. Salmon are exposed to a variety of bacterial, viral and parasitic organisms throughout their life cycle, contracting diseases through both waterborne pathogens and through mingling with infected hatchery fish (NMFS 1998). It is possible for a fish to be infected with one or more pathogen but not to show signs of disease. Hatchery Chinook salmon appear to be more susceptible to disease than naturally spawning Chinook (NMFS 1998). Because Chinook salmon in the Klamath River Basin emigrate as juveniles and return to spawn when water temperatures and flows approach their limits of tolerance, they are particularly susceptible to disease (Moyle et al. 2008, NMFS 2009).

In 2002, a major fish kill occurred in the second half of September in the lowermost 40 miles of the Klamath River main stem. At least 33,000 Chinook died out of a total estimated run of 130,000 fish (NRC 2004). Although the original FWS report of estimated mortality claimed about 33,000 fall Chinook died in this fish kill, a more updated report by CDFG explains that the estimate was "conservative and DFG analyses indicate actual losses may have been more than double that number" (CDFG 2004). This was the largest known pre-spawning die-off recorded for the region and possibly the whole Pacific coast (Guillen 2003). Stressful environmental conditions in 2002 allowed columnaris and ich to sweep through a population of already stressed fish (Guillen 2003). Factors which combined included high temperatures, crowded conditions and low flows. In response to high water temperatures and low flows, fish stopped migrating and instead concentrated in cooler deep pools, creating optimal conditions for the proliferation of pathogens. All of the specimens examined during the fish kill were infected by ich and/or columnaris (Guillen 2003).

Columnaris is a bacterial infection affecting Upper Klamath Chinook salmon and is caused by *Flavobacterium columnare*. The disease is associated with pre-spawn mortality of spring-run Chinook especially when they are exposed to above-optimal water temperatures (Moyle et al. 2008). Columnaris is usually pathogenic at temperatures above 15º C and outbreaks are common in adult populations held at hatcheries in water at 15-18º C (Guillen 2003). The earliest sign of columnaris is a thickening of the mucus at various spots on the fish (Guillen 2003). When it becomes more developed, fish will show small bloody spots on the skin. Eventually, respiratory and osmoregulatory function is lost at the gill surface and the fish dies (Post 1987). Although typically widespread, columnaris only causes widespread mortality when associated with high degrees of stress. This occurred during the 2002 fish kill in which columnaris was one of the two diseases implicated as a direct cause of mortality. By 2004, only 2.4% of fish examined were infected with *F. columnare* suggesting that it was not a significant problem in these fish in 2004 (Nichols and Foott 2005).

The other pathogen which directly caused the major fish kill in 2002 is ich disease, caused by the ciliated protozoan, *Ichthyopthirius multifilis*. The optimal temperature for ich development is 21.1-23.9º C and within this range, higher temperatures cause faster replication of the parasite (Guillen 2003). Ich disease reduces the capacity for fish to absorb oxygen and excrete ammonia and mortality occurs when gills become too damaged to function (Post 1987). Studies show that higher water velocities reduce and may prevent ich disease outbreaks completely because of a decreased probability of the parasite finding a host before being swept downstream (Guillen 2003).

The USFWS and CDFG monitored the health and physiology of salmonids in the Klamath and Trinity River Basins from 1991-1994 and identified *Ceratonova shasta* as the most significant disease affecting juvenile salmon in the Klamath Basin (Nichols and Foott 2005). *C. Shasta* is a myxozoan parasite that appears in the mainstem and Upper Klamath River, Copco Reservoir, both Klamath and Agency Lakes and the lower reaches of the Williamson and Sprague Rivers (Moyle et al. 2008). It is often found in reservoir environments so that dams on the Klamath River have contributed to the spread of this parasite. Soon after Iron Gate Hatchery was established, operational problems associated with *C. shasta* began to occur and significant outbreaks continued to occur into the early 1980s (NMFS 1998). A 1989 study found that Chinook salmon at Iron Gate Hatchery had a 4% susceptibility to *C. shasta* and a 19% susceptibility at the Trinity River Hatchery (Carlton 1989 as cited in NMFS 1998). *C. shasta* infection appears to be accelerated when high densities of infected fish are combined with warm water temperatures (Foott et al. 2003).

Nichols and Foott monitored the health of juvenile Klamath River Chinook Salmon. They estimated that 45% of the population was infected with *C. shasta* (Nichols and Foott 2005). Of the fish infected with *C. shasta,* 98% were also infected with another myxozoan infection, *Parvicapsula minibicornis*. The dual infection suggested that the majority of fish infected with *C. shasta* as juveniles would not survive.

More recent studies have revealed some of the factors affecting incidence of *C. shasta* infections and identified this parasite as a potentially limiting factor to the survival of Klamath River Chinook. Petros et al. (2007) studied the effect of water flows on the incidence of *C. shasta* to find out whether drought exacerbated fish health issues by concentrating spores in reduced flows and compromising resistance through increased stress from warm water temperatures. The years 2005 and 2006 had higher flows than 2004 and exposure to *C. shasta* was less severe in the years with higher flows. However, the 2006 results were not as pronounced as expected given the magnitude of the spring 2006 water levels (Petros et al. 2007).

Bjork and Bartholomew (2009) investigated the effects of water velocity on presence of *C. shasta* in *Manayunkia speciosa,* the pathogen's intermediate polychaete host. In faster water velocities, the polychaete density was higher but the prevalence of *C. shasta* was lower and the severity of infection in fish was also decreased. Another study by Bjork (2010) showed that temperature had no effect on polychaete survival but that higher temperatures caused actinospore release in *C. Shasta* to occur earlier and in greater abundance. *C. shasta* infections can be expected to grow more severe in conditions of low flows and high temperatures.

Parvicapsula minibicornis the other myxozoan parasite common to the Klamath River and although often present, like *C. Shasta* it is not always abundant nor do the conditions always exist for large numbers of

Chinook salmon to be infected (Moyle et al. 2008). *P. minibicornis* appears to be highly infectious. It was estimated to infect 94% of the population of juvenile Chinook in the Klamath River in 2004 (Nichols and Foott 2005).

Another prevalent pathogen in the Klamath River Basin is Bacterial Kidney Disease (BKD) caused by the Bacterium, *Renibacterium salmoninarum.* In 1994, BKD was cited along with the trematode parasite, *Nanophyetus salmicola,* as one of the most significant pathogens affecting both natural and hatchery smolt health in the Basin (NMFS 1998). The pathogen can prevent fish from making the necessary changes in kidney function during smoltification (NMFS 1998). Also, the stress of migration can cause BKD to come out of remission (Schreck 1987).

Climate change is expected to cause increased water temperatures and therefore higher stress conditions that can be expected to increase the occurrence and severity of disease outbreaks among Chinook salmon in the Klamath Basin. Warmer temperatures favor disease outbreaks (Moyle et al. 2008). Disease has been a direct cause of mass mortalities in the Klamath Basin in the past and will present further challenges for their continued survival due to changing conditions in the future.

(6) other natural events or human-related activities.

As noted above, a century of dams and diversions has been a leading cause of UKTR Spring Chinook declines.

7. DEGREE AND IMMEDIACY OF THREAT

Please see #1, population trend

8. IMPACT OF EXISTING MANAGEMENT EFFORTS

As abundantly documented in this petition, Upper Klamath Chinook face severe threats from multiple factors. Existing regulatory mechanisms are entirely inadequate to address these threats and ensure the survival of the species. By considering Upper Klamath spring- and fall Chinook as part of the same ESU, NMFS has limited adequate protection of spring Chinook under the ESA so that they are directly at risk of extinction. Current federal and state regulations which may indirectly affect these fish lack the protection needed by Upper Klamath Chinook.

Federal Regulatory Mechanisms: U.S. Forest Service

In the United States, the National Environmental Policy Act (NEPA) requires Federal agencies, including agencies within the Department of Interior, Department of Agriculture (e.g. United States Forest Service), and beyond, to consider the effects of management actions on the environment. NEPA does not, however, prohibit Federal agencies from choosing alternatives that may negatively affect Upper Klamath Chinook salmon.

Upper Klamath Chinook are listed as a sensitive species by the Forest Service in Region 5, requiring analysis of impacts to the salmon from management actions or changes under NEPA. Because NEPA does not require avoidance of harm, this affords little protection. The Forest Service must analyze the impacts of their actions on the species, but as above are not required to select alternatives that avoid harm to Chinook. Indeed, the Forest Service regularly plans timber sales, maintains and utilizes roads, allows livestock grazing and conducts other actions that harm Upper Klamath Chinook.

Relevant National Forest Plans include Six Rivers National Forest, Shasta-Trinity National Forest and Klamath National Forest. The forests are responsible for maintaining suitable fish habitat that will support well-distributed, viable populations of native fish. Forest service sensitive species including the Upper Klamath Chinook are considered in planning decisions such as habitat improvement and restoration. Sensitive species are considered when establishing key watersheds within National Forest Plans. Standards and guidelines for key watersheds include analysis prior to management activities, prioritization of sensitive species during restoration activities and restrictions on the building of new roads. National Forest Plans do not have the authority to maintain fish habitat on private lands nor to regulate actions by private parties which are destructive to Upper Klamath Chinook (mining, agriculture and timber operations) and the plans are therefore insufficient to protect Chinook salmon in the Basin.

The NWFP, signed and implemented in April 1994, represents a coordinated ecosystem management strategy for Federal lands administered by the USFS and BLM within the range of the Northern spotted owl (which overlaps considerably with the freshwater range of Chinook salmon).

The most significant element of the NWFP for anadromous fish is its Aquatic Conservation Strategy (ACS). This regional scale conservation strategy includes: (1) Special land allocations, such as key watersheds, riparian reserves, and late-successional reserves, to provide aquatic habitat refugia; (2) special requirements for project planning and design in the form of standards and guidelines; and (3) new watershed analysis, watershed restoration, and monitoring processes. These components are designed to ensure that Federal land management actions achieve a set of nine Aquatic Conservation Strategy objectives, which include salmon habitat conservation. In recognition of over 300 ‘‘at-risk’’ Pacific salmonid stocks within the NWFP area (Nehlsen et al., 1991), the ACS was developed by aquatic scientists, with NMFS participation, to restore and maintain the ecological health of watersheds and aquatic ecosystems on public lands. The ACS attempts to maintain and restore ecosystem health at watershed and landscape scales to protect habitat for fish and other riparian-dependent species and resources and to restore currently degraded habitats. The approach seeks to prevent further degradation and to restore habitat on Federal lands over broad landscapes.

The overall effectiveness of the NWFP in conserving Upper Klamath Chinook salmon is limited by the extent of Federal lands and the fact that Federal land ownership is not uniformly distributed in the ESU. In some areas, particularly Bureau of Land Management (BLM) ownership, Federal lands are distributed in a checkerboard fashion, resulting in fragmented landscapes. This factor places constraints on the ability of the NWFP to achieve its aquatic habitat restoration objectives at watershed and river basin scales.

In addition, a significant portion of land in the Klamath River Basin remains open to logging under the NWFP. Land ownership in the Basin is 35 percent private, which is largely open to logging and urban and agriculture development with few protections in place for Chinook salmon or their habitat. In addition, there are over 700,000 acres, or roughly 16% of the basin, of Bureau of Land Management and the U.S. Forest Service lands that are designated as matrix lands under the Northwest Forest Plan, which are largely open to logging.

Under the National Forest Management Act, the Forest Service is required to “maintain viable populations of existing native and desired nonnative vertebrate species in the planning area” (36 C.F.R. §219.19). As with NEPA, this requirement does not prohibit the Forest Service from carrying out actions that harm species or their habitat, stating only that “where appropriate, measures to mitigate adverse affects shall be prescribed” (36 C.F.R. §219.19(a)(1)). This clause does little to limit long term impacts to salmonid habitat in the Klamath Basin. Also, these regulations are currently under review and any protection they afford may be removed at any time.

Despite all of these laws and plans, federal land managers have continued to plan and implement projects that harm Upper Klamath-Trinity River Chinook salmon. Destructive actions have included timber sales on steep slopes, logging of riparian reserves, failure to maintain, fix and remove roads as necessary, and problems with grazing, including inadequate and unenforced best management practices (BMPs). Also, the U.S. Forest service has failed to advocate for stream flows in the lower Scott River which is under their jurisdiction. Federal land managers in the Basin are not taking sufficient actions to manage for the persistence of Chinook salmon and better practices are necessary for conservation of these fish.

Federal Regulatory Mechanisms: FERC

The Federal Energy Regulatory Commission (FERC) is charged with relicensing the Klamath Hydroelectric Project (FERC P-2082-000) on the Klamath River every 20 to 50 years. The FERC license for operation of the Klamath Project expired in 2006 and FERC produced an Environmental Impact Statement (EIS) for the Project in 2007. In a new national era of dam removal, FERC has supported negotiations regarding removal of antiquated hydroelectric projects like on the Klamath River in place of intensive and costly dam improvements to comply with modern environmental laws. PacifiCorp and the Klamath River Renewal Corporation (KRRC) recently filed applications with FERC to transfer the dams to KRRC for license surrender and dam removal. FERC's decision on the application is pending.

When considering whether or not to list a species, NMFS is not to consider promised, pending or future management actions, but instead only the current management and status of the species. In numerous ESA listing cases, the USFWS has been forced by judicial action to reverse decisions not to list species because they relied on promised management actions; this includes decisions over the Barton Spring's salamander, Queen Charlotte goshawk, jaguar, Alexander Archipelago wolf, and coho salmon. It is imperative that NMFS consider only the current management and species status. States, federal agencies, and private interests can easily promise to protect and recover species in order to avoid or delay a potentially controversial listing; unfortunately, there are not means to ensure management agencies will follow through on promises, or that their actions will result in recovery. To protect species from ongoing destruction, modification or curtailment of habitat or range, listing under the ESA is required while management actions are being tested. If promised management actions result in substantial recovery, then such actions should be incorporated into a recovery plan for the species.

In response to the noted court decisions on various species' listings, USFWS developed a policy for evaluating the contribution of conservation efforts while considering the potential need for listing. This policy identifies criteria for determining the certainty a conservation effort and whether it is likely to be effective. (68 Fed. Reg. No. 60, 28 Mar. 2003). We have considered this policy when evaluating pending agreements in the Klamath Basin, and understand that NMFS should do the same when considering listing of the Upper Klamath Trinity River spring Chinook salmon. Clearly, the UKTR Spring Chinook is experiencing ongoing threats, placing it in danger of extinction and thus requiring protection as an endangered species, regardless of pending, untested, or promised management actions

The most recent genetic work on spring-run Chinook in the Klamath Basin suggest that even with dam removal, the lack of the spring-run timing allele in Upper Klamath Chinook source populations within a reasonable distance below the current dams will hinder restoration and natural spring-run Chinook recovery after dam removal. "These results highlight the need to conserve and restore critical adaptive genetic variation before the potential for recovery is lost." (Thompson, et al. 2018)

State Regulatory Mechanisms: TMDL

State mechanisms which affect Upper Klamath Chinook and their habitat include the establishment of Total Maximum Daily Loads (TMDLs) for chemical pollution in the Klamath River. The Klamath River is listed as a water quality impaired river under Section 303(d) of the Clean Water Act and as required by the Act, states are required to establish TMDLs for instate impaired waterways. Enforceability of TMDLs is difficult and insufficient. The continued occurrence of dangerous algal blooms in reservoirs in this river system clearly illustrates the inadequacy of this regulation. Federal regulators recently adopted new TMDLs calling for a 57% reduction in phosphorous and a 32% reduction in nitrogen and a 16% cut in carbonaceous biochemical oxygen from wastewater. Although the new TMDLs are intended to protect salmon resources, there are no implementation programs in place for controlling pollutant inputs from land use. Without these implementation plans, standards are unlikely to be met.

State Regulatory Mechanisms: Mining

California instated a ban on suction dredge mining in 2009 in response to a lawsuit from the Karuk Tribe referencing damage to fish habitat and water quality. This ban is clearly beneficial for Upper Klamath Chinook. However, the ban is temporary until the California Department of Fish and Game completes an environmental review of suction dredge mining. There is no guarantee that this mining practice will not be reintroduced after the environmental review occurs.

Federal and State Regulatory Mechanisms: Fishing

Fishing harvest allocations are decided annually based on input from federal, state, regional, and tribal bodies. In general, tribes maintain the right to fifty percent of the total annual harvest. Within tribal and non-tribal fishing, further allocations are assigned for commercial ocean fisheries, sport, and subsistence fishing. Harvest quotas are based on projections for run size each year and attempt to maintain a minimum spawning escapement of 35,000 fish to protect the runs for the long-term. Overfishing is an aggravating factor to the grim future of Upper Klamath Chinook; fishing regulations alone will not provide for the continued existence of this ESU.As noted above in section 6.2 over-exploitation, because managing agencies do not treat spring-run Chinook differently from fall-run Chinook, spring-run fish are taken legally in commercial and sport fisheries (Moyle et al. 2008). Further enhancing the problem, current management actions neglect to protect spring-run Chinook even when protections have been put in place to restrict fall-run Chinook harvest, essentially increasing pressure on the much smaller and more imperiled populations of spring-run Chinook, as took place in 2017 when fall-run Chinook harvest was closed on the Klamath River to all fishing while bag limits remained the same during the spring run period.

Federal and State Regulatory Mechanisms: California Forest Practices Rules

California Forest Practices Rules are developed under the California Forest Practices Act of 1943 which governs logging practices on all private lands. These rules are inadequate to prevent harm to Upper Klamath Chinook.

Regulatory Mechanisms: Climate Change

Current global, national, and state climate change legislation and agreements are entirely inadequate to prevent ocean acidification and the variability of other ocean conditions aggravated by climate change. As noted, these conditions pose a significant threat to the long-term survival of salmonids in their marine environment.

Greenhouse gas emissions and resulting climate change is among the least regulated threats to Upper Klamath Chinook. The primary international regulatory mechanisms addressing greenhouse gas emissions and global warming are the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Copenhagen Accord. While the entering into force of the Kyoto Protocol on February 16, 2005 and the development of the Copenhagen accord in December, 2009 mark significant partial steps towards the regulation of greenhouse gases, they do not and cannot adequately address the impacts of global warming that threaten the Upper Klamath Chinook.

Choices about emissions now and in the coming years will have far-reaching consequences on the magnitude of climate change impacts. The longer greenhouse gas emissions reductions are delayed, the more severe the global impacts will be (Karl et al. 2009). If global warming is going to be limited to 2°C above pre-industrial values, global emissions need to peak between 2015 and 2020 and then decline rapidly (Allison et al. 2009). This will require average annual per-capita emissions to shrink to under one metric ton CO_2 per capita. This is 80-95% below the per capita emissions in developed nations in 2000 (Allison et al. 2009).

There are currently no legal mechanisms regulating greenhouse gases on a national level in the United States. The immediate reduction of greenhouse gas pollution is essential to slow global warming and ultimately stabilize the climate system in order to maintain and restore Upper Klamath Chinook habitat.

For the reasons discussed, existing and proposed regulatory mechanisms are indisputably inadequate to ensure the continued survival of the Upper Klamath Chinook salmon.

9. **SUGGESTIONS FOR FUTURE MANAGEMENT**

The steeper decline of UKTR Spring Chinook relative to fall-run UKTR Chinook stems in great part from their need to spend more time as an adult in fresh water during summer months when flows are low. Historically, the Klamath Basin offered unfettered access to higher elevation flood plain habitat and spring fed cold water refugia for adult UKTR Spring Chinook. Today, access to much of these habitats is blocked by dams, cold water springs are diverted for agricultural purposes and flood plains physically altered by mining or sedimentation associated with poor logging practices and road maintenance. Hatchery practices both at the Trinity at Iron Gate hatcheries may negatively impact genetic integrity, variability, and fitness of UKTR Spring Chinook. In addition, UKTR Spring Chinook are particularly susceptible to the warming trends associated with global warming and prolonged droughts.

In light of these facts, we suggest the following future management actions be considered:

i. Remove the lower four Klamath River dams consistent with the terms of the Klamath Hydroelectric Settlement Agreement and PacifiCorp's pending application before FERC.

ii. Currently, the Salmon River and South Fork Trinity sub-basins offer the largest spawning populations of the UKTR Spring Chinook in the Klamath system. These sub basins should be managed explicitly for the restoration, protection, and management of UKTR Spring Chinook.

iii. The Shasta River should be managed as a cold-water refuge, restrictions should be placed on agricultural diversions affecting flow and temperature, ground water extraction should be limited and removal of Dwinnell dam should be considered.

iv. The Scott River should be managed for UKTR Spring Chinook, which means restrictions should be placed on agricultural diversions affecting flow and temperature, ground water extraction should be limited, and removal of Young's Dam should be considered.

    a. Manage the Salmon River as a UKTR Spring Chinook refuge and prioritize restoration projects aimed to restore floodplain habitat affected by historic mining and minimizing impacts associated with logging projects and grazing.Implementation of the Salmon River Floodplain Habitat Enhancement and Mine Tailing Remediation Plan and recommended restoration projects.

b. Potential restoration and enhancement actions for the Salmon River include the following:

i. Protecting and expanding cold water refuges at summer baseflow within the mainstem channels and lower reaches of major tributaries to improve holding and summer rearing habitat conditions;
ii. Adding structure within simplified channel reaches (e.g., plane-bed morphology) that promotes hydraulic complexity and pool depth, increasing the amount and quality of low velocity rearing habitat, and sorting spawning gravel;
iii. Manipulating (e.g., grading and/or adding structure) and revegetating floodplains to improve hydrologic function and processes, primarily by increasing flow connectivity (e.g., frequency and duration of inundation) and hyporheic exchange between the winter baseflow channel (20% exceedance flow), bankfull side channels (1.5- to 2-year flow), and high flow side channels (≥5-year flow);
iv. Adding structural complexity to side channels to improve rearing habitat;
v. Creating, enhancing, and connecting off-channel ponds and wetlands to improve rearing habitat; and
vi. Grading and revegetating mine tailings on floodplains and adjacent terraces to increase riparian shading, reduce heating, and improve hyporheic exchange.

c. Implement key actions from the collaboratively developed Salmon River In-stream Candidate Action Table and the Middle Klamath In-stream Candidate Action Table.

v. Develop limiting factors analysis for Klamath River spring-run Chinook for the Klamath River and all tributaries within the historic range of spring-run Chinook.

vi. Conduct assessments and develop restoration action plans to address the impacts of historic mining throughout key tributaries and the mainstem of the Klamath Basin.

vii. Develop on comprehensive Klamath Basin spring-run Chinook recovery plan and associated restoration action plan.

viii. Develop restoration actions and priorities for reducing the impacts of sediment inputs from roads, logging, and other activities into rivers of the Klamath-Trinity system, especially on public lands.

ix. Prevent dewatering of habitats and limit effects of pesticides/herbicides associated with legal marijuana cultivation through permitting programs.

x. Develop a program to investigate impact(s) of the Trinity River Hatchery on UKTR Spring Chinook populations (e.g., number of hatchery-reared fishes spawning in the wild, genetic shifts in population) and manage hatchery production accordingly. Rates of hybridization between spring-run and fall-run Chinook and relative fitness of the offspring should be paid particular attention.

xi. Investigate whether a conservation hatchery can play a role in facilitating re-colonization of Klamath River tributaries by UKTR Spring Chinook after dam removal occurs. If such an approach is explored, efforts must be made to reduce genetic impacts of founder’s effects and inbreeding/outbreeding depression.

xii. Limit recreational in-river harvest to a mark-selected fishery for 100% adipose fin clipped Trinity River Hatchery produced spring-run Chinook to keep them separate from wild fish.

xiii. Ban suction dredge mining in all areas deemed current or potential habitat.

xiv. Restore headwaters and high mountain meadow systems throughout the basin and in particular in key spring-run Chinook watersheds to maximize cold water storage, lengthen cold water releases, and promote resiliency in the face of climate change.

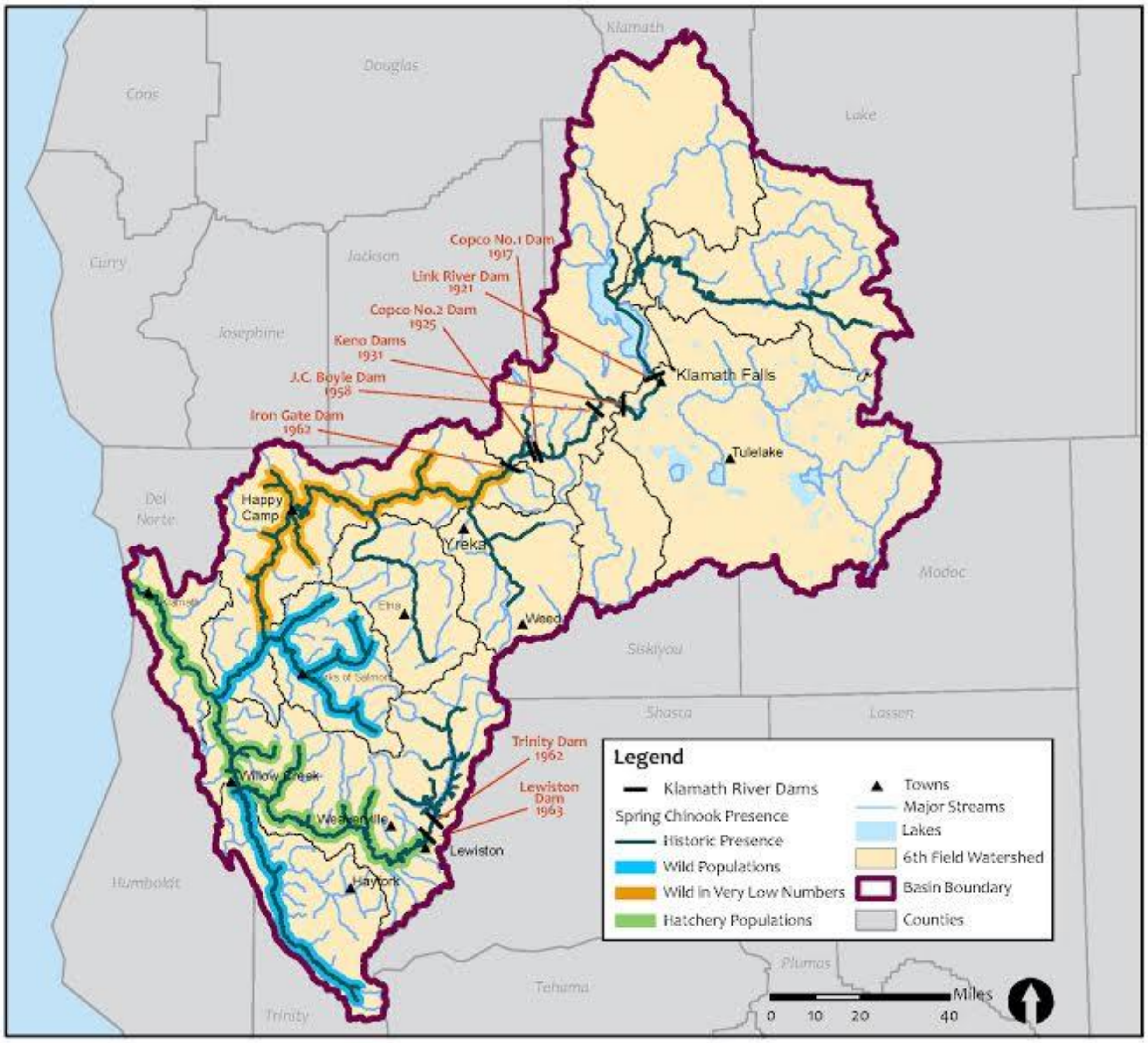
xv. Restore healthy fire process at a landscape scale on the Klamath Basin through increased use of prescribed fire, managed wildfire, and associated fuels treatments.

xvi. Implement the Western Klamath Restoration Partnership Plan (Harling, Tripp, 2014)

10. **AVAILABILITY AND SOURCES OF INFORMATION**

Please see bibliography at the end of attached NMFS petition

11. **DETAILED DISTRIBUTION MAP**



Klamath Trinity spring-run Chinook current and historic distribution map, created by SRRC from available data, 2015.

12. ADDITIONAL INFORMATION

Legal/Regulatory Background

Recognizing that certain species of plants and animals have become extinct “as a consequence of man’s activities, untempered by adequate concern for conservation,” (Fish & G. Code § 2051 (a)) that other species are in danger of extinction, and that “[t]hese species of fish, wildlife, and plants are of ecological, educational, historical, recreational, esthetic, economic, and scientific value to the people of this state, and the conservation, protection, and enhancement of these species and their habitat is of statewide concern.”

(Fish & G. Code § 2051 (c)) the California Legislature enacted the California Endangered Species Act (CESA).

The purpose of CESA is to “conserve, protect, restore, and enhance any endangered species or any threatened species and its habitat....” (Fish & G. Code § 2052). To this end, CESA provides for the listing of species as “threatened” and “endangered.” The Commission is the administrative body that makes all final decisions as to which species shall be listed under CESA, while the Department is the expert agency that makes recommendations as to which species warrant listing. The listing process may be set in motion in two ways: “any person” may petition the Commission to list a species, or the Department may on its own initiative put forward a species for consideration. In the case of a citizen proposal, CESA sets forth a process for listing that contains several discrete steps.

Upon receipt of a petition to list a species, a 90-day review period ensues during which the Commission refers the petition to the Department, as the relevant expert agency, to prepare a detailed report. The Department’s report must determine whether the petition, along with other relevant information possessed or received by the Department, contains sufficient information indicating that listing may be warranted. (Fish & G. Code § 2073.5).

During this period interested persons are notified of the petition and public comments are accepted by the Commission. (Fish & G. Code § 2073.3). After receipt of the Department’s report, the Commission considers the petition at a public hearing. (Fish & G. Code § 2074). At this time the Commission is charged with its first substantive decision: determining whether the Petition, together with the Department’s written report, and comments and testimony received, present sufficient information to indicate that listing of the species “may be warranted.” (Fish & G. Code § 2074.2). This standard has been interpreted by as the amount of information sufficient to "lead a reasonable person to conclude there is a substantial possibility the requested listing could occur."[1] If the petition, together with the Department’s report and comments received, indicates that listing “may be warranted,” then the Commission must accept the petition and designate the species as a “candidate species.” (Fish & G. Code § 2074.2.)

Once the petition is accepted by the Commission, then a more exacting level of review commences. The Department has twelve months from the date of the petition’s acceptance to complete a full status review of the species and recommend whether such listing “is warranted.” Following receipt of the Department’s status review, the Commission holds an additional public hearing and determines whether listing of the species “is warranted.” If the Commission finds that the species is faced with extinction throughout all or a significant portion of its range, it must list the species as endangered. (Fish & G. Code § 2062.) If the Commission finds that the species is likely to become an endangered species in the foreseeable future, it must list the species as threatened. (Fish & G. Code § 2067.)

Notwithstanding these listing procedures, the Commission may adopt a regulation that adds a species to the list of threatened or endangered species at any time if the Commission finds that there is any emergency posing a significant threat to the continued existence of the species. (Fish & G. Code § 2076.5).[2]

Unlike ESA, CESA does not contain a definition of “species” or “subspecies” in its text, nor does it determine whether or not an Evolutionarily Significant Unit (ESU), as defined in the Federal Endangered Species Act (ESA) and detailed below, may be listed as an Endangered Species under CESA. However, in *California Forestry Assn. v. California Fish & Game Comm.*, it was determined that “the [California]

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[1] *Natural Resources Defense Council v. California Fish and Game Comm.* 28 Cal.App.4th 1104 at 1125, 1129.

[2] See also *Central Coast Forest Assn. v. Fish & Game Comm.* 2 Cal. 5th 594 at 599.

legislature did not want to limit the term ‘species or subspecies’ to the federal definition. Instead the legislature likely may have wanted to leave the interpretation of that term to the Department…and to the Commission”.[3] Further, the decision elaborated that the Department and the Commission have a “longstanding adherence to the policy that the CESA allows listings of evolutionary significant units”.[4] Thus, if there is sufficient evidence to show that a subset of a species should be considered an ESU under ESA, the Commission and Department should consider a petition for listing that subset as its own Endangered Species under CESA.

The Federal Endangered Species Act defines “species” to include “any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.” 16 USC § 1533(16), *see also California State Grange v. National Marine Fish,* 620 F.Supp 2d 1111, 1121 (ED Cal 2008). The ESA does not define the term “distinct population segment.” *Grange* at 1121.

In 1991 the National Marine Fisheries Service (“NMFS”) promulgated its *“Policy on Applying the Definition of Species Under the Endangered Species Act to Pacific Salmon”* or “ESU Policy.” (56 Fed.Reg.58612 (Nov. 20, 1991)). The ESU Policy provides that a population of Pacific salmonids is considered to be an ESU, and therefore considered for listing under the ESA, if it meets the following two criteria:

(i.) It must be substantially reproductively isolated from other nonspecific population units; and
(ii.) It must represent an important component in the evolutionary legacy of the species. Isolation does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue in different population units. The second criterion would be met if the population contributes substantially to the ecological/genetic diversity of the species as a whole (Waples 1991). Grange at 1123-24.

NMFS uses all available lines of evidence in applying those criteria, including specifically data from DNA analyses (“…data from protein electrophoresis or DNA analysis can be very useful because they reflect levels of gene flow that have occurred over evolutionary time scales.”), *ESU Policy,* 56 Fed. Reg. at 58518; *see also Definition of “Species” Under the Endangered Species Act: Application for Pacific Salmon,* NOAA Tech Memo NMFS F/NWC-194 (Waples 1991) at p.8 (“The existence of substantial electrophoretic or DNA differences from other conspecific populations would strongly suggest that evolutionarily important, adaptive differences also exist.”)

The ESU Policy is an interpretation by NMFS of what constitutes a “distinct population segment,” and is a “permissible agency construction of the ESA.” *Grange* at 1124, citing *Alsea Valley Alliance v. Evans,* 161 F.Supp2d 1154, 1161 (D.Or. 2001).

When considering whether a species or subspecies, including an ESU, is endangered, NMFS must consider:

i. The present or threatened destruction, modification, or curtailment of its habitat or range;
ii. Overutilization for commercial, recreational, scientific, or educational purposes;
iii. Disease or predation;
iv. The inadequacy of existing regulatory mechanisms; or
v. Other natural or manmade factors affecting its continued existence.
16 U.S.C. § 1533(a)(1).

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[3] *California Forestry Assn. v. California Fish & Game Comm.* 156 Cal. App. 4th 1535 at 1549.

[4] Ibid at 1546.

The species shall be listed where the best available data indicates that the species is endangered because of any one, or a combination of, those five factors. 50 CFR § 424.11(c).

Any interested person may submit a written petition to list a species or subspecies as threatened or endangered. 50 CFR § 424.14(a).

The newly proposed 50 CFR §424.14(g)(1)(iii) states that petitions filed after an adverse ruling will be considered only where "new information or analysis such that a reasonable person conducting an impartial scientific review would conclude that the action proposed in the petition may be warranted, despite the previous determination." 81 Fed. Reg. 23454-55. NMFS states further that the proposed §424.14(f) will "clarify" the Service's position that any supplemental petition will be considered with the previous petition, and they together will reset the statutory periods for response—constructively the same as filing a new petition. 80 Fed. Reg. 29289 (21 May 2015).

Factual Background

Chinook salmon in the upper Klamath and Trinity Rivers are currently regulated and managed as a single ESU referred to as Upper Klamath Trinity River (UKTR) Chinook, with no distinction between seasonal runs. The Klamath Trinity spring (KTS) Chinook is not defined as its' own unique ESU, and is not listed as threatened or endangered. Water management, fisheries management, and other regulatory activities are generally conducted without consideration of potential impacts on KTS Chinook, instead considering impact to UKTR Chinook generally. This approach may be having an adverse impact on KTS Chinook especially when hatchery practices are considered

In an effort to explain differences in run timing observed in Chinook salmon populations, conservation geneticists offer two possible explanations for the evolution of spring, or "premature," migration patterns for salmonids: a monophyletic pattern of evolutionary history versus a polyphyletic pattern of evolutionary history. These models are based on a comparison of the DNA structure of fall and spring run individuals within the same watershed versus nearby watersheds using a variety of genetic techniques.

In evaluating whether to list seasonal runs as Evolutionarily Significant Units ("ESU") for purposes of the Endangered Species Act, the National Marine Fisheries Service ("NMFS") considers which of these two evolutionary models apply to the given population. Because spring and fall run fish fitting the polyphyletic pattern evolve from a common ancestor based on environmental factors, the genetic material for both seasonal runs are contained in fish from both runs. The evolutionary changes necessary to give rise to the phenotype are relatively easy to reproduce since, according to this model, it has happened many times in closely related populations. NMFS has argued that even if spring run migrating subpopulations were extirpated by flow diversions, barriers, or other factors, the spring migration phenotype could easily re-emerge if appropriate habitat was later restored. On that basis, polyphyletic pattern fish runs typically do not meet NMFS guidance requirement to qualify as an ESU. According to Waples, "*Although the failure of most stock transfers indicates that local populations may be largely irreplaceable on human time frames, at least some patterns of Chinook salmon life history diversity appear to be evolutionarily replaceable, perhaps over time frames of a century or so. The evidence for repeated parallel evolution of run timing in Chinook salmon indicates that such a process is likely, provided that habitats capable of supporting alternative life-history trajectories are present and sufficient, robust source populations are maintained"* (Waples et al. 2004).

In contrast, seasonal fish runs that evolved via the monophyletic pattern evolved from a separate ancestor, and are genetically distinct from other fish runs in that river system. Thus if extirpated, monophyletic seasonal fish runs are likely gone forever, and thus warrant classification as an ESU, as well as the protections that result from such a listing.

Until now, most conservation geneticists considered most spring run Chinook populations to fit the polyphyletic model. This would mean that fish from a common ancestor evolve genetic differences due to the reproductive isolation and natural selection driven by the unique features of their respective watersheds. According to this explanation, these separate populations later evolved the early migration or ‘spring run’ phenotype independently from each other. In other words, the spring run phenotype evolved many times over in neighboring populations. The application of the polyphyletic model to these populations stems from studies that show that the genetic structures of spring and fall run individuals within a watershed are more genetically similar than spring run individuals from different watersheds. Examples of runs thought to be a product of this process include spring and fall run Chinook in the Rogue and Umpqua (Waples et al. 2004).

However, in some fish populations the DNA structure of fall and spring run individuals within the same watershed are less similar to one another than those in neighboring watersheds. These observations suggest an alternative explanation for the evolutionary basis for the early migration phenotype. In these cases, the difference in run timing is attributed to a monophyletic pattern of evolutionary history. Under this model the genetic changes that give rise to differences in run timing predate the genetic differences that arise as a consequence of geographic isolation. Until now, the only known examples of monophyletic based premature migration are among spring run and fall run Chinook salmon in the mid and interior Columbia and Snake River basins, and winter, spring and fall run Chinook populations in California’s Central Valley. The fish in each of these seasonal runs are more closely related to each other than to Chinook salmon in any other basin, or to other Chinook salmon runs in the same tributary river (Meyers et al 1998; Banks et al 2000a; Garza et al 2007). Some researchers argue that the differences observed in the Central Valley spring and fall populations stem more from anthropogenic factors associated with hatchery management than with a true evolutionarily event.

In summary, conservation biologists consider most populations of spring Chinook salmon to be a product of polyphyletic evolution, except in a few rare exceptions where it is not.

In a memo summarizing the finding of the Biological Review Team (BRT) report on the 2011 Petition, the Science Director of the National Marine Fisheries Service Southwest Fisheries Science Center, Francisco Werner, noted that “One reviewer expressed the personal view that there is evidence for reproductive isolation and adaptive divergence between Klamath River spring-run and fall-run Chinook salmon and thus merit their own ESU. However, the reviewer found that spring-run Chinook salmon in the UKTR basin do not represent a unique component of the evolutionary legacy of the species, and therefore, do not meet one of the two requirements for recognition as an ESU under NMFS’ ESU policy (the other requirement being long-term reproductive isolation resulting from an unique evolutionary event that is unlikely to re-evolve over ecological time-scales)”(Werner 2011). However, recently published work challenges the assertion that spring run Chinook does not meet the other requirement. The study shows that a unique evolutionary event was the cause for the spatial and temporal reproductive isolation that spring and fall run exhibit in the UKTR, and shows that spring run life type Chinook are unlikely to re-evolve over ecological time scales (Prince et al. 2017).

2011 Petition for Listing UKTR Chinook

In 2011, Center for Biological Diversity (CBD) et al. filed an Endangered Species Act (ESA) listing petition (“2011 Petition”) with NMFS to address the dramatic declines of Klamath River spring Chinook salmon. CBD *et al*. suggested 3 alternatives for NMFS to consider: 1) list spring run Chinook as their own evolutionary significant unit (ESU); 2) list spring run Chinook as a distinct population segment (DPS) within the previously recognized UKTR Chinook ESU; or 3) list the entirety of the UKTR Chinook ESU (Center for Biological Diversity et al. 2011).

In its initial response to the 2011 Petition, the NMFS Southwest Region (SWR) determined that "… the literature cited in the petition, and other literature and information available in our files, we found that the petition met the criteria in our implementing regulations at 50 CFR 424.14(b)(2) that are applicable to our 90-day review and determined that the petition presented substantial information indicating that the petitioned action may be warranted the petition presented substantial new scientific information thereby indicating that the petitioned actions may be warranted" (National Marine Fisheries Service 2011) (76 FR 20302; April 12, 2011).

In that 90-day finding, NMFS narrowed the scope of their pending further review. In particular, the agency explained that it would not consider Petitioners' second alternative for listing Chinook salmon in the UKTR ESU as a DPS. Instead, NMFS determined that the analysis would consider whether the KTS Chinook constitutes an ESU. NMFS noted that their Policy on Applying the Definition of Species Under the Endangered Species Act to Pacific Salmon, "…explains that a Pacific salmon stock will be considered a distinct population segment, and hence a "species" under the ESA, if it represents an ESU of the biological species" (ESU Policy; 56 FR 68612; November 20, 1991).

2011 Biological Review Team Determination

After determining that the petition actions met the appropriate criteria and may be warranted, NMFS convened a Biological Review Team (BRT) which considered the 2011 Petition and over 50 written comments from the public. Specifically, the BRT considered two fundamental issues: 1) 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) assessment of the biological status of the supported ESU configuration using the viable salmonids population framework (Williams et al. 2011).

In the 2011 Petition, CBD et al. argued that the KTS Chinook evolved via the monophyletic pattern, and thus qualified for listings as an ESU. CBD pointed to new genetic data, and argued that KTS Chinook show genetic and life history divergence from fall run UKTR Chinook equal or greater than those of the Central Valley spring and fall run Chinook ESUs.

The BRT reviewed the new genetic data brought forth by CBD et al. The BRT did not agree based on the data that a monophyletic evolutionary model best described the prevalence of the KTS Chinook. Rather, the BRT argued that a polyphyletic evolutionary history best explained the 'premature' migration pattern observed within the UKTR Chinook ESU. While acknowledging some genetic differences between various UKTR Chinook runs, the BRT concluded that the genetic and life history differences of the KTS Chinook were not great enough to warrant the designation of ESU status. The BRT stated,

> *"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 went on to conclude that considered as a whole population, UKTR Chinook were not threatened or endangered, stating:

> *"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*"(ibid.)

The results and conclusions of the BRT report was the basis of the 12 month finding published in the Federal Register on April 2, 2012 which rejected the 2011 Petition of CBD et al. to list KTS Chinook salmon (National Marine Fisheries Service 2011).

Recent Technology, Data and Analysis

NMFS' 2011 conclusion was consistent with the large body of literature based on genetic analyses performed using microsatellites. While these studies often revealed genetic differences between geographically isolated populations, they failed to consistently demonstrate significant differentiation between premature and mature migrating phenotypes within a watershed (Kinziger et al. 2013; Waples 1991; Nielsen, Crow, and Fountain 1999). As a consequence, early migration phenotypes, including the KTS Chinook, have been largely grouped into the same ESU or DPS as mature migration phenotypes.

Until recent advances in genetic analysis, researchers were limited by the available technology in how they could study the genetic differences between closely related populations. Previously, researchers looked for relatively large differences in genetic structure, which often appear in genomic regions not influence by environmental pressures and natural selection, because the available technology allowed this sort of analysis. These genomic regions vary due to gene flow and genetic drift, as opposed to being driven by environmental pressures and natural selection. The weakness of this approach is that it lacks the molecular resolution necessary to detect evolutionarily significant adaptations that may stem from changes in sequence and structure in specific genomic regions, particularly in regions that encode genes.

Although the relatively large body of data is indeed consistent with the hypothesis that polyphyletic evolution explains premature run timing (at least in most cases), the evidence is also consistent with another explanation – that premature run timing is the result of a changes in genetic sequence or structure of specific regions of the genome that predates the polyphyletic changes brought on by geographic isolation. Until recently conservation geneticists lacked the tools necessary to fully explore the latter hypothesis. However, recent advances in technology now allow researchers to comb through genomes at a much higher resolution cheaply and quickly. Previously, researchers would rely on dozens or maybe hundreds of molecular markers to search for genetic differences between subpopulations. Today, researchers can quickly compare millions of genetic regions to look for differences.

Based on the technical limitations of genetic analysis, the previous approach to determining the evolutionary history of the premature migration phenotype was inferential. In other words, conservation geneticists inferred the evolutionary history of the phenotype based on demography not adaptation. The new technology now allows researchers to locate individual genomic regions that are the actual cause of evolutionary change, and reconstruct the evolutionary history of these regions directly. This direct reconstruction of the evolutionary history of the spring run Chinook versus fall run Chinook has now been performed and recently published in a peer reviewed journal (Prince et al. 2017).

Prince et al. created a high-resolution genomic library from samples of spring and fall migrating adult Chinook and steelhead from several Pacific Northwest watersheds, including the Klamath. The researchers then created high-resolution restriction-site associated DNA (RAD) libraries, sequenced them, and aligned the sequences to a recent salmonid genome draft. The genomic libraries generated from individual fish where then compared using a probabilistic framework to discover small nuclear polymorphisms (SNPs). Although Prince et al. notes that the initial analysis was consistent with current DPS and ESU delineations, the sheer volume of genomic positions they went on to compare (nearly 10 million) allowed a thorough comparison of premature and mature migrating individuals. This revealed several SNPs within a couple hundred thousand base pairs of one another. Further analysis revealed this region to be within the GREB1L gene. This result was then repeated in other populations including UKTR Chinook. Prince et al. notes that this finding makes biological sense in that this gene is implicated in foraging and fat storage in mammals. In salmon, premature migrating Chinook have a significantly higher fat content than mature migrating individuals, consistent with the fact that early migrating individuals are destined to climb higher into watersheds before spawning and thus need more stored energy.

Prince et al. went on to sequence the GREB1L region in all of their samples and created a gene tree based on parsimony. The tree revealed two monophyletic groups corresponding to migration phenotype. All samples, regardless of watershed of origin, separated into the appropriate migratory clade. In other words, Prince et al. found that all premature migrating individuals evaluated grouped together in the same monophyletic group. Thus, genetic differences in this single gene explain the difference between premature and mature migrating phenotypes. Although NMFS has argued that "some patterns of Chinook salmon life history diversity appear to be evolutionarily replaceable, perhaps over time frames of a century or so…"(Waples et al. 2004), premature migration clearly does not fall into this category as explained in greater detail below.

Without the advent of molecular tools that allow for the cheap and quick creation of detailed DNA libraries (collectively referred to as Next Generation Sequencing or NGS), the identification of a single gene that is responsible for such a complex phenotype would have been nearly impossible. Now that the technology is available and has been applied, however, the monophyletic nature and evolutionary significance of UKTR Spring Chinook must be acknowledged.

UKTR Spring Chinook

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 (Williams et al. 2011). This Petition presents precisely that genetic information for the upper Klamath Trinity River system Chinook populations. 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), it must be shown that these populations are substantially reproductively isolated from other conspecific population units and that they represent an important component in the evolutionary legacy of the species. Prince et al. makes that demonstration.

It is well established that spring Chinook, by virtue of entering fresh water rivers during snow melt, reach spawning areas that are, generally, reproductively isolated from their fall run counterparts (Quinn 2005). Waples' 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. For spring run Chinook, Prince et al. demonstrate that the molecular basis for the spring run phenotype is associated with a defined allele that evolved long ago in Chinook evolutionary history. Prince et al. found evidence of only two allelic evolutionary events that produced a premature migration allele, one in Chinook and one in steelhead, even though the species diverged approximately 15 million years ago. This is in contrast to the assertion by the BRT review of the previous KTS Chinook petition which concluded, without the benefit of Prince et al.'s recent findings, that the spring run phenotype is polyphyletic in origin and evolved independently in many locations.

Prince's recently published data clearly demonstrate that contrary to prevailing dogma, Klamath-Trinity spring Chinook exhibit a monophyletic pattern of evolutionary history, and meet Waples' and NMFS' criteria for a separate ESU.

A more recent publication (Thompson et al. 2018) further strengthens this argument and calls into question any assertion that Klamath spring-run Chinook will reemerge from Chinook heterozygotes once the spring-run phenotype is lost:

> "using a new marker identified through a high-resolution, multi-population analysis of GREB1L suggests that 1) the association of migration type with variation at GREB1L is extremely robust and 2) heterozygotes have an intermediate migration phenotype.

> Therefore, while phenotypic variation within each genotype (e.g., precise freshwater entry and spawning dates) is yet to be explained, migration type (i.e., premature/spring-run or mature/fall-run) appears to have a strikingly simple genetic architecture. Furthermore, the association of a single haplotype with the spring-run phenotype in diverse locations supports a previous conclusion that spring-run alleles arose from a single evolutionary event and cannot be expected to readily re-evolve (Prince et al., 2017; Miller et al., 2012). Thus, simple modes of inheritance and rare allelic evolutionary events can underpin complex phenotypic variation.”

Citing evidence that heterozygotes are selected against, Thompson et al. conclude that that, “where the spring-run phenotype is lost, spring-run alleles should not be expected to be maintained in the heterozygous state… both theory and empirical evidence suggest heterozygotes are not a sustainable reservoir for spring-run alleles, and human factors can eliminate important adaptive variation regardless of total population size.”

As previously noted, the criteria for an ESU designation are that 1) it must be substantially reproductively isolated from other nonspecific population units; and 2) it must represent an important component in the evolutionary legacy of the species.

Prince et al. 2017 demonstrates that KTS Chinook are an important component in the evolutionary legacy of UKTR Chinook and that the reproductive isolation between spring and fall run populations is strong enough to permit evolutionarily important differences to accrue. Thompson et al. 2018 further demonstrate the point.

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November 8, 2017

Principal Deputy Assistant Secretary John Tahsuda III
Office of the Assistant Secretary - Indian Affairs
Department of the Interior
1849 C Street, N.W.
MS-4660-MIB
Washington, D.C. 20240

Re: Karuk Tribe's Inquiries on the Ruffey Rancheria Restoration Act of 2017

Ayukii (hello) Principal Deputy Assistant Secretary Tahsuda:

The Karuk Tribe writes to you to express questions that it has regarding H.R. 3535, the Ruffey Rancheria Restoration Act of 2017, and requests that the United States Department of Interior ("DOI") provide a response before this bill is scheduled for a mark-up within the House of Representatives.

The Karuk Tribe is the second largest federally recognized tribe in California with over 3800 tribal members. The Karuk Tribe has existed since time immemorial in the mid-Klamath Basin and presently has three districts located in Siskiyou and Humboldt Counties within two national forests. We are also the largest federally recognized tribe in Siskiyou County and provide critical services to the surrounding community—such as medical, dental, behavioral health, head start, etc—based on our negotiated service area as a self-governance tribe.

On September 29, 2017, the Karuk Tribe learned about H.R. 3535 from a Siskiyou Daily News[1] article that discussed the Shasta People and the September 26, 2017 hearing on the bill in the United States House of Representatives ("House") Subcommittee on Indian, Insular and Alaska Native Affairs. The Karuk Tribe had never been contacted about this proposed restoration nor had it known that the terminated Ruffey Rancheria had a purported reconstructed existence and leadership. Upon learning about this bill, Karuk Tribe staff and leadership have conducted

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[1] http://www.siskiyoudaily.com/news/20170929/lamalfa-bill-could-restore-siskiyou-tribes-federal-recognition

ongoing outreach to learn more about this bill and I have specifically requested a meeting between the Karuk Tribal Council and the Ruffey Rancheria leadership or between the Karuk Tribal Council and Chairman Tahj Gomes. See Attachment 1. To date, this request has not been accepted.

Because we have not been able to obtain a meeting with the Ruffey Rancheria, despite our best efforts, we are directing our questions to DOI. We will continue to concurrently work on outreach to the Ruffey Rancheria.

I. Karuk Descendent Enrollment Eligibility in Reconstructed Rancheria

Presently, the Karuk Tribe has approximately 4,000 registered descendents. While not enrolled as tribal members, the Karuk Tribe like many indigenous nations considers its descendents to be a part of its broader community and often acts to protect their welfare and rights as Karuk People. As introduced, the bill's broad enrollment provisions would allow the Karuk Tribe's 4000 descendents to potentially obtain enrollment within the Ruffey Rancheria. Further, Karuk descendents have a valid interest in the Rancheria because it had a Karuk connection at creation and termination because its namesake, Old Man Ruffey, was a Karuk Indian as were the Rancheria's final distributees.

Given the Karuk history of this Rancheria and the important rights that attach to membership within a federally recognized tribe, our Karuk descendents are reasonably interested in their ability to become ***presently*** enrolled within the reconstructed Ruffey Rancheria prior to congressional restoration. Present enrollment is critical because HR 3535 provides that current members of the Ruffey Rancheria will become immediately eligible for all federal benefits and services on the date the bill is passed. Specifically, HR 3535 provides:

> (c) Federal services and benefits.—
>
> (1) IN GENERAL.—Without regard to the existence of a reservation, *the Tribe and its members shall be eligible, on and after the date of the enactment of this Act, for all Federal services and benefits furnished to federally recognized Indian Tribes or their members*. For the purposes of Federal services and benefits available to members of federally recognized Indian tribes residing on a reservation, members of the Tribe residing in the Tribe's service area shall be deemed to be residing on a reservation.

See HR 3535, Sec. 2(c)(1)(emphasis).

Currently, Karuk descendents cannot access information regarding their present eligibility for enrollment within the reconstructed Ruffey Rancheria. Section 5 of the Bill, references the existence of a December 19, 2014 tribal constitution for the Ruffey Rancheria and states that this document will be the basis for interim governance of the Rancheria after restoration. However, a search of the congressional record and an internet search could not find this document. As shown in the attached correspondence, the Karuk Tribe has requested a meeting with the executive leadership of the Ruffey Rancheria to specifically address this eligibility inquiry. To date, the invitation to meet with our leadership has not been accepted.

As shown, within a month of learning of this bill, the Karuk Tribe has worked diligently to locate information regarding Ruffey Rancheria enrollment opportunities for Karuk descendents. Our earnest effort has yielded no answers and instead has raised further questions regarding the origin and reconstruction of the Ruffey Rancheria that we believe are fundamental to addressing questions of enrollment. For example, Chairman Gomes' testimony references the elders of the Ruffey Rancheria and states that the "California State legislature petitioned Congress to provide the group with a reservation in 1874." See Attachment 2, p. 1. However, the submitted exhibit does not support this representation. Instead, the exhibit shows that that the requested reservation was sited in Quartz Valley, Siskiyou County, where the Quartz Valley Indian Tribe is presently located. See Attachment 2, p. 4. Thus it is unclear whether the reconstructed Ruffey Rancheria is asserting an interest in the assigned territory of another Siskiyou County federally recognized tribe. This confusion in the legislative record is particularly problematic as the bill permits the restored Rancheria to site their new reservation *anywhere* within Siskiyou County and the gaming provisions of the bill require, in part, an aboriginal connection. From the congressional record, it appears that the reconstructed Rancheria asserts an aboriginal connection to Quartz Valley.

Another ambiguity is the relationship between the allotments referenced in Chairman Gomes' testimony and the original 441 acres of the Rancheria's reservation. Chairman Gomes stated that the BIA "also acquired individual land allotments for other members of our tribe." It is not clear whether the BIA, at the creation of the Ruffey Rancheria, acquired these off-reservation allotments for ***then members of the original Ruffey Rancheria*** or whether these allotments are for individuals who have ***become members of the reconstructed Rancheria*** and do not have a lineal descendency to the Ruffey Rancheria's original distributees. Clarification on this question is important because many unrecognized California Indians hold individual allotments that were not due to their membership within a federally recognized tribe. Their respective tribes are required to petition for federal acknowledgement through the administrative process.

If an unrecognized California Indian can (1) obtain membership within a reconstructed Rancheria without a showing of lineal descent to a distributee; and (2) assert that their individual allotment retroactively relates to a terminated Rancheria, this would have precedential value for California's 78 tribes that are petitioning for recognition, for the 10 other terminated Rancherias that have not been restored, and for the surrounding communities of federally recognized tribes.

These examples demonstrate that a DOI analysis of the Ruffey Rancheria's origin, termination, and purported reconstruction is needed to address enrollment inquiries. Towards that goal, in addition to the above inquiries, the Karuk Tribe submits the following questions:

1. **Rancheria Creation**
   a. What is the origin of the Ruffey Rancheria; how was it created?
   b. Was the Ruffey Rancheria for any landless Indian anywhere within Siskiyou County?
   c. Was its prior reservation contiguous or was it comprised of individual allotments?
   d. Who were the original members of the Ruffey Rancheria and where were they geographically located?
   e. Did the pre-terminated Ruffey Rancheria have a service area that included all of Siskiyou and Shasta Counties?
   f. Did the original Ruffey Rancheria have an overlapping aboriginal territory with Quartz Valley? If not, would the submitted legislative record and HR 3535 support a claim by the Rancheria that its new aboriginal territory preempts the aboriginal territories of other federally recognized tribes within Siskiyou and Shasta Counties?
   g. Does the BIA have a copy of the 1919 lawsuit, referenced in Chairman Gomes' testimony, that the BIA purportedly filed on behalf of the Ruffey Rancheria members?
   h. Page 2 of Chairman Gomes' congressional testimony references a documentary record showing "substantial confusion by the BIA about the legal arrangements of the 1907 land purchase and allotments." We request a copy of this documentary record and clarification by DOI on this description of the BIA's actions in 1907.
2. **Termination**
   a. How was the Ruffey Rancheria terminated and who were its then members at termination?
   b. Page 2 of Chairman Gomes' congressional testimony states that the BIA did not notify "qualifying members" of their tribal interests or rights at termination and, as result, a "great many irregularities occurred in the process." What does the phrase "qualifying member" mean and is their documentary evidence to support the assertions in this congressional testimony?
   c. Does DOI have internal analysis regarding the Tillie Hardwick case, referenced on page 2 of Chairman Gomes' testimony, in which then Ruffey Rancheria members sought restoration via that case and in which "original

land assignments" had been sold. We also request clarification on whether the referenced sale was of assignments or allotments.

3. Re-Construction

a. How was the Ruffey Rancheria reconstructed after termination? Did the DOI have a role in this reconstruction?

b. Mr. Tahsuda's congressional testimony states that ordinarily to assist terminated tribes, "the Department would refer back to the distributees and their descendents to formally organize." Who are the executive leadership of the Ruffey Rancheria and has DOI verified that they are the distributees named at termination or descendents of said distributees?

c. Is enrollment in the reconstructed Ruffey Rancheria limited to those of Shasta ancestry?

d. Are Karuk descendents presently eligible for enrollment within the Ruffey Rancheria and what is the process for submission of their enrollment applications?

4. Membership and Service Areas

a. Has DOI analyzed why HR 3535 includes Shasta County as a service area for the reconstructed Rancheria which was originally located in Etna, CA? What is the legal effect of having a tribe's congressionally designated service area extend outside of the county where a bill purports to restrict a reservation's situs?[2]

b. The bill designates Siskiyou and Shasta Counties as Ruffey Rancheria's service areas, does this designation congressionally pre-empt the negotiated service areas of other federally-recognized tribes such as the Karuk Tribe, Quartz Valley Indian Tribe, Redding Rancheria, and Pit River?

    i. Has the DOI assessed the impact of a congressional preemption on the funding and delivery of critical services that these tribal communities presently operate?

    ii. Does the DOI believe that it has a trust responsibility to, at the minimum, notify these federally recognized tribes of the potential impact of this legislation?

c. Has the reconstructed Rancheria disclosed its present membership numbers to DOI?

d. From the bill, it appears that DOI is in possession of documents that enumerate the Indian ancestry of those within Siskiyou County as referenced in HR 3535. Based upon these documents, has DOI estimated the projected

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[2] In contrast to HR 3535, in P.L. 106-568, the restored Graton Rancheria's service areas were co-extensive with the eligible locations for its reservation.

> membership of the reconstructed Rancheria? If so, has DOI performed an analysis of the anticipated costs for fulfillment of its trust responsibilities to this new community?

Lastly, with regards to membership eligibility for Karuk descendents, the Karuk Tribe is concerned that the Karuk ancestry of the original Ruffey Rancheria has not been adequately disclosed and thus Karuk descendents have not been made aware of their eligibility for present enrollment. We base this concern, in part, on the referenced September 29, 2017[3] local news article which informed us of this bill and focused on the Shasta People and expressed the county's support for the "efforts of the Shasta peoples to gain federal recognition." The county's support letter was listed in Chairman Gomes' congressional testimony and the contents of the conversation between Ruffey Rancheria leadership and the Siskiyou County Board of Supervisors are not a matter of public record. We thus have a reasonable basis for believing that Karuk descendents have not known of their enrollment eligibility in the reconstructed Ruffey Rancheria.

II. Reservation Situs

HR 3535 allows the Rancheria to restore their reservation anywhere within Siskiyou County. See HR 3535, Sec 3 (a) ("Upon application by the Tribe, the Secretary shall have the authority under this section to accept into trust for the benefit of the Tribe not more than 441 acres of real property located in Siskiyou County, California...."). The Karuk Tribe has contacted Ruffey Rancheria to inquire about the location of this potential reservation because we would like to avoid an overlap with our aboriginal territory. Chairman Gomes responded, in his October 21, 2017 letter, that he could not address "the location of any lands that may ultimately be *ceded* to the Ruffey Rancheria." See Attachment 1. HR 3535, however, does not appear to set forth a land cessation or exchange.

We request clarification from DOI whether such a request has been made by Ruffey Rancheria and if so, has DOI assessed or plan to assess how to avoid an overlap with the Karuk Tribe's aboriginal territory?

The Karuk Tribe also seeks clarification on whether, under Section 3(a), the 441 acre reservation must be contiguous land parcels or whether it can consist of parcels distributed throughout the county. Clarification on this question is needed because, as highlighted above, Chairman Gomes' congressional testimony raises questions as to whether Ruffey Rancheria was a contiguous reservation or whether it consisted of individual allotments.

Further, an analysis is needed on the rights that attach under Section 2(d) of the bill which provides that "[n]othing in this Act shall expand, reduce, or affect in any manner any hunting,

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[3] http://www.siskiyoudaily.com/news/20170929/lamalfa-bill-could-restore-siskiyou-tribes-federal-recognition

fishing, trapping, gathering, or water rights of the Tribe and its members." If the restored Rancheria sites its new reservation adjacent to the Sacramento River, will it acquire water and fishing rights for a membership which may exceed 4000 if just Karuk descendents are counted? In the alternative, would Section 2(d) be interpreted only according to the then-existing rights that were held by the Ruffey Rancheria distributees, at their Etna location, who were listed at termination?

The above inquiries demonstrate that siting a reservation *anywhere* within California's fifth largest county raises logistical questions that require thorough DOI analysis to ensure that (1) the trust responsibility to existing federally recognized tribes, such as the Karuk Tribe, are upheld; (2) ambiguities regarding Ruffey Rancheria's reservation composition are addressed; and (3) to explain the rights that attach to a reservation that could be located on waterways that are critical to California's water infrastructure and fish harvest management.

III. HR 3535 Gaming Provisions

Section 7 of the bill permits gaming to be conducted on land if 25 CFR Part 292 is satisfied and Ruffey Rancheria demonstrates a substantial, direct, modern and aboriginal connection to the land taken into trust. Section 8(8) of the bill shows that the substantial, direct, modern connection can be satisfied by showing that the gaming trust property is within a ***25 mile radius of their site where their reservation is requested within five years of the Act's enactment.*** Section 9(9) shows that a substantial, direction, aboriginal, connection to the land "means those lands that the Secretary determines are within a 25-mile radius of culturally significant sites to the Tribe, the area in which the language of the Tribe was spoken; or the historical presence of the Tribe on the land."

Implementation of Section 7 raises many practical questions. First, it appears that off-reservation gaming is expressly allowed because the gaming location has to be within a radius of the reservation site, not within it. ***Since the gaming site can be off-reservation, it is unclear if the gaming site can also be outside the exterior bounds of Siskiyou County*** because only the Section 3 reservation is limited to Siskiyou County.

Second, Section 8(8) does not limit the number of off-reservation gaming sites as long as they are within a 25 mile radius of the Section 3 reservation. Thus, Section 8(8) could allow a casino to be sited within two different 25 mile radiuses of the Section 3 reservation. If the reservation is non-contiguous as inquired about above, this casino situs question is even more confusing.

Third, it is unclear how the criteria for Section 9(9) would be applied to a restored Rancheria with a membership that is of mixed Indian ancestry, of which the number of potential tribal ancestries is unknown. For example, what is the standard of review for the Secretary determining that a site is culturally significant to a "Tribe" that could consist of Karuk, Shasta, Klamath, Hoopa, Yurok, Modoc, etc? Similarly, can the "language" of the Tribe consist of multiple languages that would just need to have been spoken by a single historical member of the pre-terminated Rancheria? How much evidence has to be submitted to show that a language was used within an area? Likewise, if Ruffey Rancheria's casino is located anywhere within Siskiyou County, how can it as a "Tribe" show a historical presence on the land when it never existed as a "Tribe" on the land until after restoration?

In summary, our inquiries demonstrate that Section 7 of the bill also requires further analysis to resolve ambiguities over implementation of its provisions. Claims of reservation shopping and battles over off-reservation gaming have been a source of lengthy litigation in California for tribes and their surrounding communities and we believe it is in the best interest of all parties to resolve these issues to avoid this expensive acrimony. Further it is notable that the last restoration bill that Congress passed, the Graton Rancheria Restoration Act, contained no reference to gaming.

IV. Conclusion

The Karuk Tribe thanks you in advance for consideration of our questions. We look forward to working with DOI, Congressman Douglas L. LaMalfa, and Ruffey Rancheria to address the Karuk Tribe's inquiries and, if necessary, make recommendations to the bill to avoid inter-tribal issues. We especially believe clarification on the several membership issues that we have raised is a critical element of this bill's progress.

To that end, we respectfully request that our questions be addressed prior to a bill-mark up to enable the applicable House committee to make informed decisions within the mark-up process.

Yootva (thank you),

Karuk Chairman
Russell 'Buster' Attebery

Enclosures

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WATER QUALITY CONTROL PLAN

February 2014

Prepared By

The Karuk Tribe

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Orleans, California

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With Technical Support from:

Riverbend Sciences

Aquatic Ecosystem Sciences, LLC.

CONTENTS

FORWARD

The need for comprehensive water quality planning is set forth in Karuk Tribe laws under Resolution 96-R-24. The Federal Water Pollution Control Act as amended by the Clean Water Act of 1977 requires water quality control plans for the waters of tribes as well as public review of the plans. The basic purpose of the Karuk Tribe's planning effort is to determine the future direction of water quality control for protection of Tribal waters.

The enclosed *Water Quality Control Plan* is comprehensive in scope. It contains a brief description of Tribal trust property located along the middle portion of the Klamath River, and describes the present and potential beneficial uses of the surface and ground waters. The water quality objectives contained in the report are prescribed for the purposes of protecting the beneficial uses. The implementation plans section describes the measures, which include specific prohibitions, action plans, and policies which form the basis for the control of water quality.

Tribal plans and enforcement mechanisms are included. The report contains provisions for public participation, complies with the requirements of CWA Section 303, and establishes a setting and the framework for the development of discharger regulations.

Integral to the Water Quality Control Plan implementation process is the provision for change. In that respect, the Water Quality Control Plan is reviewed triennially to determine the needed changes and to keep pace with technologies, policies, changes in the law, and physical changes within the lands held in trust. The Water Quality Control Plan was first developed in 2002 and then updated in 2014. The technical basis for the 2014 revisions is provided in a companion document titled *Justification for Revisions Proposed in the Karuk Tribe's 2014 Water Quality Control Plan* (Asarian and Kann 2014).

1.0 INTRODUCTION

1.1 Purpose

The primary responsibility for the protection and enhancement of water quality on trust property has been assigned to the Karuk Tribe's Department of Natural Resources. The Department of Natural Resources proposes water quality standards which recognize the unique characteristics of cultural uses, natural water quality conditions, and both actual and potential beneficial uses of tribal waters.

The purposes of the water quality standards for the trust lands are outlined below:

- To designate uses for which Tribal waterbodies of the trust lands shall be protected
- To prescribe water quality standards imposed to sustain designated uses of Tribal waterbodies
- To assure that degradation of existing water quality does not occur
- To promote the social welfare, cultural, and economic well-being of the Karuk Tribe

These purposes will be accomplished by incorporating the water quality standards established herein into the permitting and management process for point source dischargers and nonpoint source generators, by using these water quality standards to determine when a designated use is threatened, and by using (1) current treatment technologies to control point sources and (2) best management practices to control nonpoint sources of pollution.

Water quality standards for the trust lands are designed to meet the federal provisions of the Clean Water Act (CWA) as they relate to surface water sources. The water quality standards are consistent with Section 101(a)(2) of the CWA, which declares that "it is the national goal that, wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water to be achieved by July 1, 1983...."

The CWA requires tribes and states to develop water quality standards that include designated uses and criteria to support those uses for navigable waters. CWA Section 502(7) defines navigable waters as waters of the U.S. Waters of the U.S. are defined in federal regulations developed for the National Pollutant Discharge Elimination System (NPDES) (40 CFR § 122.2) and permits for the discharge of dredged or fill material (40 CFR §§ 230.3, 232.2). Waters of the U.S. include waters subject to the ebb and flow of the tide; intertribal waters (including intertribal wetlands) and intratribal waters (including wetlands), the use, destruction, or degradation of which could affect intertribal commerce; tributaries of the above; and wetlands adjacent to the above waters.

1.2 Location of the Karuk Trust Lands

The Tribal trust lands include properties situated along the middle portion of the Klamath River and its tributaries in Northern California (Figures 1 and 2). The Karuk tribe administers approximately 1,168 acres of tribal trust and private domain allotments. The northern most allotment is located on the Klamath River just north of the town of Happy Camp. The southernmost allotment is situated just south of the town of Orleans along the Klamath River. Karuk Tribe trust lands contain approximately 11.37 miles of perennial and intermittent rivers and streams.

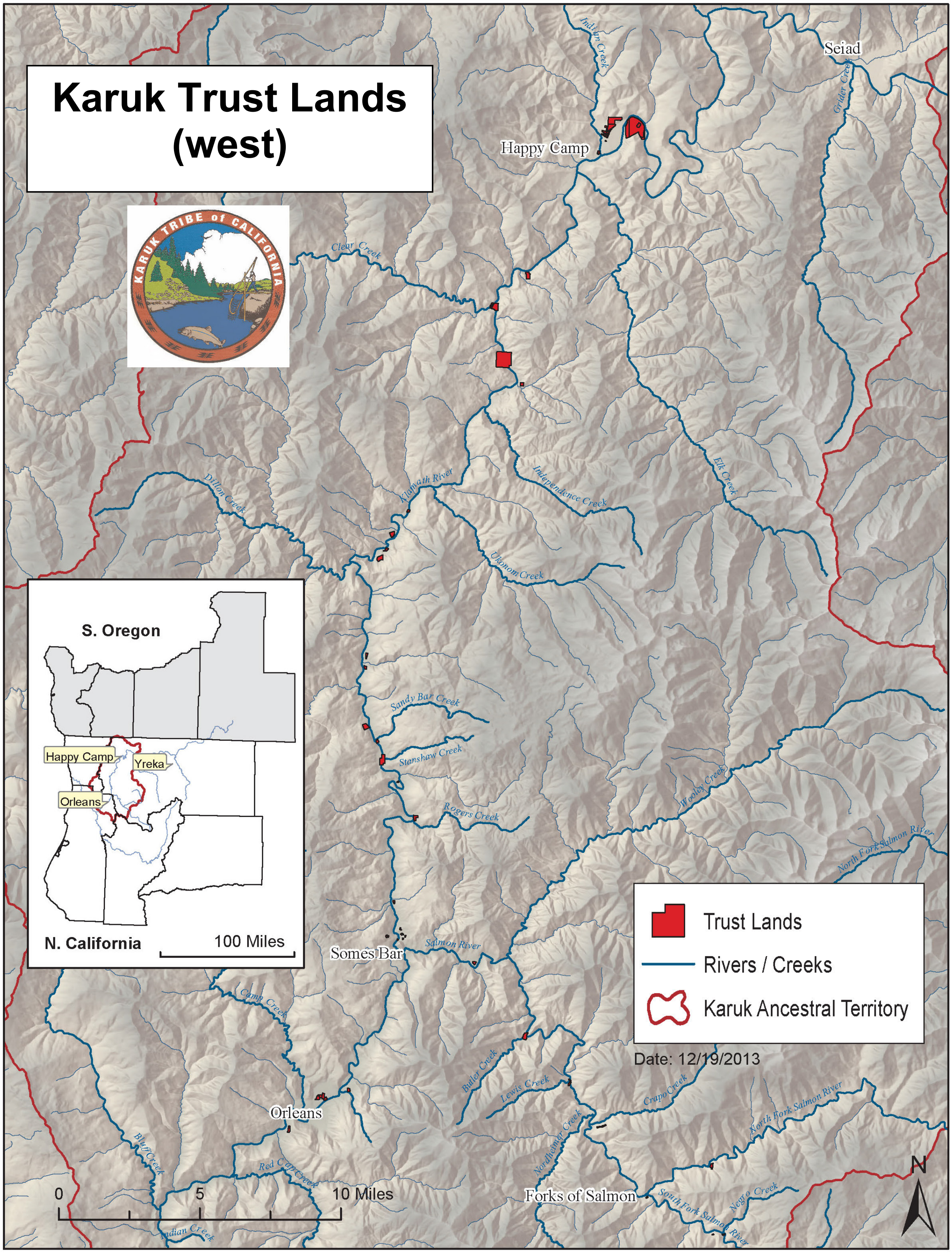

Figure 1. Map of Karuk tribal trust lands between Seiad and Orleans.

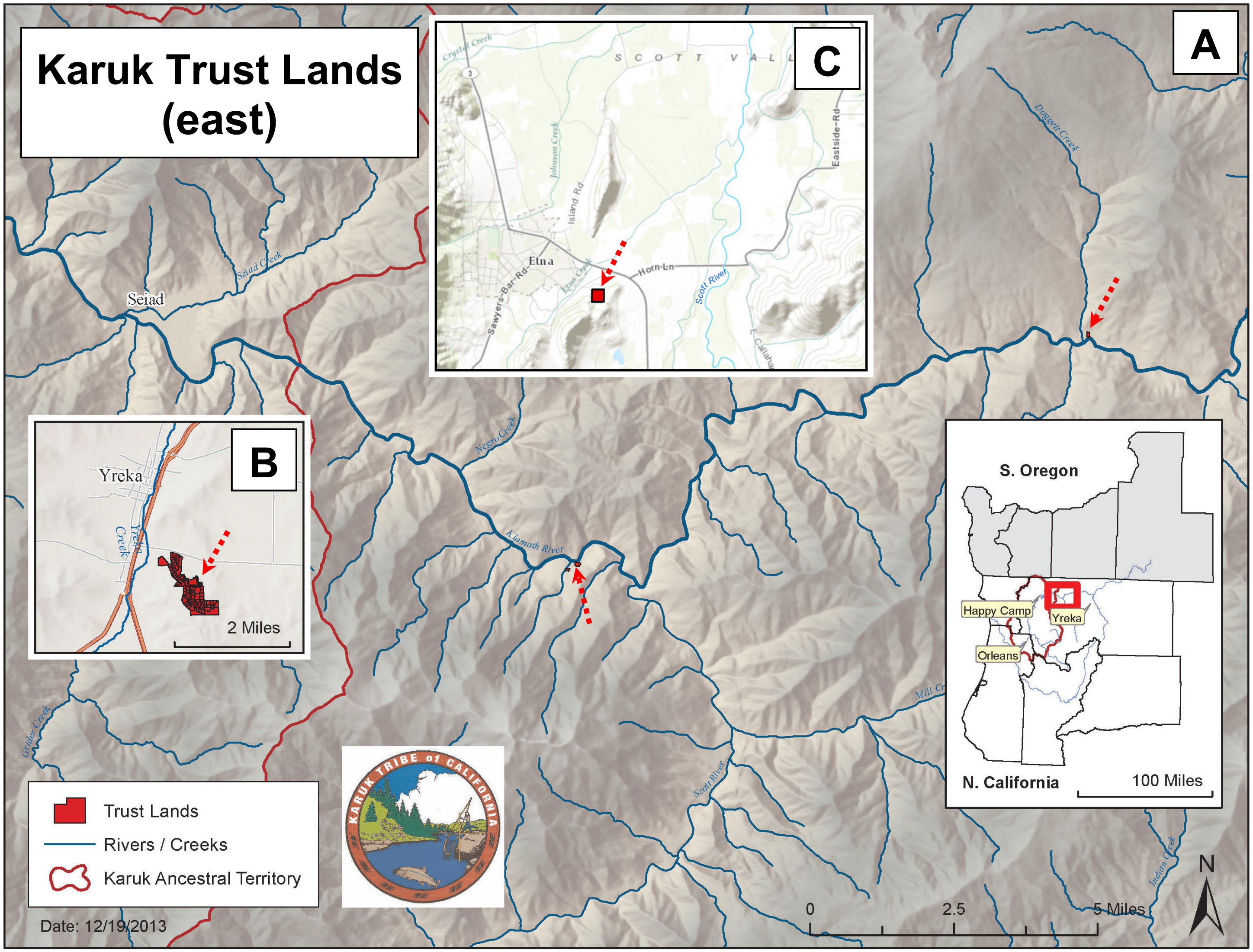

Figure 2. Map of Karuk tribal trust lands along the Klamath River east of Seiad (A), in the Shasta Valley near Yreka (B), and in the Scott Valley near Etna (C). Red arrows visually highlight trust lands.

1.3 Authority

Pursuant to Tribal Resolution No. 00-R-17 and Sections 518 and 303(c) of the federal Clean Water Act, the Karuk Tribe, organized pursuant to the Indian Reorganization Act of 1934, hereby adopt the water quality standards for the trust lands.

The federal Clean Water Act (Section 303, 33 U.S.C. § 1313) requires tribes and states to adopt water quality standards for navigable waters of the United States and to review and update those standards on a triennial basis under the oversight of the Region IX U.S. Environmental Protection Agency (EPA).

1.4 Applicability

These water quality standards apply to all Tribal waterbodies within the boundaries of the trust lands including both surface and ground waters.

1.5 Triennial Review and Public Participation

Pursuant to Section 303(c)(1) of the CWA 33 U.S.C. Section 1313[c]), the Karuk Tribe will hold public hearings at least once every 3 years to review and, as appropriate, amend the water quality standards. Revisions to the water quality standards will incorporate cultural concerns, updated EPA quality criteria for water, and relevant scientific and engineering advances.

The Department of Natural Resources is responsible for this triennial review, and is required to: 1) identify those portions of the trust lands which are in need of modification or new additions; 2) adopt standards as appropriate; and 3) recognize the portions of the water quality standards which are appropriate as written. The review includes a public hearing process, thus providing a forum for the public to raise issues for the Department of Natural Resources to consider for incorporation into the water quality standards for the trust lands.

Public participation is a key element in both tribal and federal planning requirements. Federal public participation requirements of 40 CFR Part 25 apply. The public participation requirements are intended to foster public awareness and the open processes of tribal governmental decision-making. The Department of Natural Resources seeks to implement public participation requirements by requesting the public's input, assimilating its viewpoints and preferences, and demonstrating that those viewpoints have been considered. A notice of proposed actions relating to water quality standards for the trust lands will be published in area newspapers and distributed to a list of interested persons or organizations.

The Water Quality Control Plan was first developed in 2002 and then updated in 2014.

SECTION 2.0 DEFINITIONS

The terms in this document associated with water quality standards shall have the following meanings:

7DADM - Seven-day average of the daily maximums.

Acute toxicity - Toxicity involving a stimulus severe enough to rapidly induce a response. In aquatic toxicity tests, an effect observed in 96 hours or less is considered acute.

Aesthetic Quality (ASQ) - Use of water that supports visual quality objectives including, but not limited to, the odor, taste and appearance (which includes stagnation and the presence of oil and foam) of the water.

Agricultural Supply (AGR) - Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

Ambient Stream Temperature- The stream temperature measured at a specific time and place. The selected location for measuring stream temperature must be representative of the stream in the vicinity of the point being measured.

Antidegradation Policy - The policy set forth in USEPA water quality standards regulations under the CWA whereby existing uses and the level of water quality necessary to maintain those uses is maintained and protected (see 40 CFR § 131.12).

Aquaculture (AQUA) - Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.

Best management practices (BMPs) - Practices undertaken to control, restrict, and diminish nonpoint sources of pollution that are consistent with the purposes of the water quality standards for the Tribal waterbodies. Included as a BMP is the practice of prevention through development provisions.

Chronic Toxicity - Toxicity involving a stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic is considered a relative term depending on the lifespan of an organism. Measurements of chronic effect can include reduced growth, reduced reproduction, etc., in addition to lethality.

Clean Water Act (CWA) - The Federal Water Pollution Control Act, as amended by the Water Quality Act of 1987.

Cold Freshwater Habitat (COLD) - Uses of water that support cold water ecosystems including, but not limited to the preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Cold Water Refugia - Those portions of a water body where or times during the diel temperature cycle when the water temperature is at least 2 degrees Celsius colder than the daily maximum temperature of the adjacent well-mixed flow of the water body.

Colony-Forming Units (CFU) - A direct count of bacteria colonies used in microbiological analyses.

Criteria - Elements of water quality standards that are expressed as pollutant concentrations, levels, or narrative statements representing a water quality that supports a designated use.

Cultural Contact Water (CUL-1) – Use of water by a member of the Karuk Tribe during a cultural or religious practice, where the human body will come into direct contact with the water. Complete submergence into, and ingestion of the water is likely to occur. Sensitive body organs, such as eyes, ears, and nose, may be exposed to prolonged contact with the water. It includes sufficient water quantity as well as quality to carry out these acts.

Cultural Non-Contact Water (CUL-2) - Use of water by a member of the Karuk Tribe during a cultural or religious practice, including but not limited to subsistence fishing and collecting wetland and riparian plants, that may cause the human body to come into direct contact with the water, but normally not to the point of complete submergence. The use is such that ingestion of the water is not likely to occur, nor will sensitive body organs, such as eyes, ears, or nose, normally be exposed to prolonged contact with the water. It includes sufficient water quantity as well as quality to carry out these acts.

Designated Use - A beneficial use of water specified in the water quality standards for the Tribal waterbodies.

Environmental Protection Agency (EPA) - U.S. Environmental Protection Agency.

Existing Use - A use that has actually occurred in a surface water, or that the water quality of a surface water allowed, on or after November 28, 1975.

Fish Consumption (FC) - Uses of water for commercial, recreational or subsistence collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

Freshwater Replenishment (FRSH) - Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).

Ground water - Subsurface waters (in a zone of saturation) that are or can be brought to the surface of the ground or to surface waters through wells, springs, seeps, or other discharge areas.

Ground Water Recharge (GWR) - Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Hydropower Generation (POW) - Uses of water for hydropower generation.

Industrial Process Supply (PROC) - Uses of water for industrial activities that depend primarily on water quality.

Industrial Service Supply (IND) - Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well repressurization.

Median – A value in an ordered set of values below and above which there is an equal number of values or which is the arithmetic mean of the two middle values if there is no single middle value.

Micrograms per liter (µg/L) - The concentration at which one microgram is contained in a volume of one liter; one microgram per liter is equivalent to one part per billion (ppb) at unit density.

Migration of Aquatic Organisms (MIGR) - Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms such as anadromous fish.

Milligrams per liter (mg/L) - The concentration at which one milligram is contained in a volume of one liter; one milligram per liter is equivalent to one part per million (ppm) at unit density.

Mixing zone - A prescribed area or volume of a surface water that is contiguous with a point source discharge where initial dilution of the discharge takes place.

Municipal and Domestic Supply (MUN) - Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

National Pollutant Discharge Elimination System (NPDES) - The point source discharge permit program established by § 402 of the CWA.

Navigation (NAV) - Uses of water for shipping, travel, or other transportation by private, military or commercial vessels.

Non-Contact Water Recreation (REC-2) - Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. The use is such that ingestion of the water is not likely to occur, nor will sensitive body organs, such as eyes, ears, or nose, normally be exposed to direct contact with the water. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

Non-Point Source (NPS) - Sources of pollutants discharged into a waterbody that are diffuse in nature and are not regulated as a point source under section 402 of the CWA.

Numeric Standard: A standard or criterion expressed using quantifiable levels or concentrations of a water quality parameter.

Oil - Petroleum in any form including, but not limited to, crude oil, gasoline, fuel oil, diesel oil, lubricating oil, or sludge.

Office of Environmental Health Hazard Assessment (OEHHA): An agency of the State of California that assess environmental health hazards.

Outstanding water - A Tribal waterbody or portion of a waterbody that has been classified as an outstanding Tribal resource water by the Karuk Tribe.

Point source - Any discernible, confined, and discrete conveyance from which pollutants are or may be discharged into a water body.

Preservation of Areas of Special Biological Significance (BIOL) - Includes refuges, ecological reserves and designated areas of special biological significance, such as environmental hot spots where special protection is required in order to protect the diversity and integrity of the area.

Rare, Threatened, or Endangered Species (RARE) - Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under federal law as rare, threatened or endangered.

Riparian areas – Areas located along the shores of a river or lake that are part of the hydrologic and ecological cycles and influence of the river or lake.

Shellfish Harvesting (SHELL) - Uses of water that support habitats suitable for the collection of filter feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.

Spawning, Reproduction, and/or Early Development (SPWN) - Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fishes.

Toxic - Pollutants (or combinations of pollutants) that may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations in any organisms or their offspring after discharge and upon exposure, ingestion, inhalation, or assimilation into such organism, either directly from the environment or indirectly by ingestion through food chains.

Tribal waterbodies - Any and all surface and ground waters (including all rivers, streams, lakes, riparian areas, ponds, wetlands, aquifers, springs, seeps, canals, irrigation and drainage ditches) that meet one or more of the following criteria, pursuant to 40CFR131.8 (3)

1. Within or adjacent to the borders of Tribal Trust Property held by the Karuk Tribe.
2. Within or adjacent to the borders of Tribal Trust Property held by the United States in trust for Indians.
3. Within or adjacent to the borders of Tribal Trust Property held by a member of the Karuk Tribe.

Use attainability analysis (UAA) - A structured scientific assessment of the factors affecting the attainment of a designated use that may include physical, chemical, biological, cultural, and economic factors.

Warm Freshwater Habitat (WARM) - Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Water Contact Recreation (REC-1) - Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, snorkeling, white-water activities, or fishing.

Wetlands - Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, cienegas, tinajas, and similar areas.

Wildlife Habitat (WILD) - Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

World Health Organization (WHO) – An agency of the United Nations that is concerned with international public health

SECTION 3.0 DESIGNATED USES

At a minimum, all Tribal waters must have designated uses that meet the goals of Section 101 (a) (2) of the CWA unless the results of a use attainability analysis (UAA) show that the CWA Section 101 (a) (2) goals cannot be achieved. These goals include providing for the protection and propagation of fish and wildlife, and for cultural, spiritual and recreational uses in and on the water. A UAA will be conducted prior to removing a designated use or adopting a subcategory of a designated use that requires less stringent water quality criteria. The Director of the Department of Natural Resources will adopt or remove designated uses and subcategories of designated uses for Tribal waters when appropriate.

Existing and potential designated uses of Tribal waterbodies, including wetlands, are listed below:

- Agricultural Supply (AGR)
- Aquaculture (AQUA)
- Aesthetic Quality (ASQ)
- Preservation of Areas of Special Biological Significance (BIOL)
- Cold Freshwater Habitat (COLD)
- Cultural Contact Water (CUL-1)
- Cultural Non-Contact Water (CUL-2)
- Fish Consumption (FC)

- Freshwater Replenishment (FRSH)
- Groundwater Recharge (GWR)
- Industrial Service Supply (IND)
- Migration of Aquatic Organisms (MIGR)
- Municipal and Domestic Supply (MUN)
- Navigation (NAV)
- Hydropower Generation (POW)
- Industrial Process Supply (PRO)
- Rare, Threatened, or Endangered Species (RARE)
- Water Contact Recreation (REC-1)
- Non-Contact Water Recreation (REC-2)
- Spawning, Reproduction, and/or Early Development (SPWN)
- Shellfish Harvesting (SHELL)
- Warm Freshwater Habitat (WARM)
- Wildlife Habitat (WILD)

If a Tribal water has more than one designated use, then the most stringent water quality criterion for a designated use applies. The Director of the Department of Natural Resources will revise, by rule, the designated uses of a Tribal waterbody if water quality improvements result in a level of water quality that permits a use that is not currently listed.

The Director of the Department of Natural Resources may, by rule, establish a mixing zone in a surface water. Mixing zones are prohibited in ephemeral waters or where there is no water for dilution.

In designating uses of a Tribal waterbody, and in establishing water quality criteria to protect those designated uses, the Director of the Department of Natural Resources will consider the applicable water quality standards for downstream or downgradient Tribal waters and will ensure that the water quality standards applicable to upstream or upgradient Tribal waters also provide for the attainment and maintenance of the water quality standards of downstream or downgradient waters.
Table 1 identifies designated uses for all Tribal waterbodies. Protection will be afforded to the existing and potential designated uses of waters of the trust lands as shown in Table 1. The designated uses of any specifically identified waterbody generally apply to all its tributaries. For unidentified waterbodies, the designated uses will be evaluated on a case-by-case basis. Table 2 provides a monthly calendar of historic, existing, and potential beneficial uses, activities, and human exposure pathways for waterbodies on Karuk trust lands.

Table 1. Designated uses of Tribal waterbodies on Karuk trust land. Tributaries are listed according to the order they enter the Klamath River (downstream list first).

Waterbody	Designated Uses																					
	AGR	AQUA	ASQ	BIOL	COLD	CUL-1	CUL-2	FC	FRSH	GWR	IND	MIGR	MUN	NAV	POW	PRO	RARE	REC-1	REC-2	SPWN	SHELL	WARM	WILD
Klamath River	x		x	x	x	x	x	x	x	x		x		x			x	x	x	x	x		x
Tributaries to Klamath River:																							
Chimmekanee Gulch	x		x	x	x	x	x	x	x	x		x	x				x	x	x	x			x
Cheenitch Creek	x		x	x	x	x	x	x	x	x		x	x				x	x	x	x			x
Rogers Creek	x		x	x	x	x	x	x	x	x		x	x				x	x	x	x			x
Stanshaw Creek	x		x	x	x	x	x	x	x	x		x	x				x	x	x	x			x
Sandy Bar Creek	x		x	x	x	x	x	x	x	x		x	x	x			x	x	x	x			x
Clear Creek	x		x	x	x	x	x	x	x	x		x	x	x			x	x	x	x			x
Indian Creek	x		x	x	x	x	x	x	x	x		x	x	x			x	x	x	x			x
Ranch Gulch	x		x	x	x	x	x	x	x	x		x	x				x	x	x	x			x
Streams in Salmon River sub-basin:																							
Salmon River	x		x	x	x	x	x	x	x	x		x	x	x			x	x	x	x			x
Butler Creek	x		x	x	x	x	x	x	x	x		x	x	x			x	x	x	x			x
Lewis Creek	x		x	x	x	x	x	x	x	x		x	x				x	x	x	x			x
Crapo Creek	x		x	x	x	x	x	x	x	x		x	x				x	x	x	x			x
North Fork Salmon River	x		x	x	x	x	x	x	x	x		x	x	x			x	x	x	x			x
South Fork Salmon River	x		x	x	x	x	x	x	x	x		x	x	x			x	x	x	x			x
Negro Creek	x		x	x	x	x	x	x	x	x		x	x				x	x	x	x			x
Streams in Shasta River sub-basin:																							
un-named tributary to Yreka Creek	x		x	x	x		x	x		x		x	x				x	x	x				x
Ground Waters	x								x	x			x										
Wetlands			x	x	x		x		x	x							x					x	x

Table 2. Monthly calendar of Historic (H), Existing (E), and Potential (P) beneficial uses, activities and exposure pathways for Tribal waterbodies. Cells are shaded by location: Klamath River and tributaries (orange), or Klamath River only (green).

Beneficial Use	Activity Types	Activity Description	Exposure Pathway	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ceremonial (CUL-1, CUL-2)	Annual Ceremonies	wading, drinking, cooking, sweating, submersion/bathing, boating	Ingestion, inhalation, dermal absorption			H,E, P*	H,E, P*	H,E, P*	H,E, P*	H, E	H, E	H, E	H, E		
	Funerals	wading, drinking, cooking, sweating, submersion/bathing, boating		H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
	Marriage	wading, drinking, cooking, sweating, submersion/bathing, boating		H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
Subsistence (CUL-1, CUL-2, FC, SHELL)	Fishing	food, dip netting, wading water/ contact	Ingestion, inhalation, dermal absorption	H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
	Mussels	food, hand gathering, wading/water contact				H,E	H,E	H,E	H,P	H, P	H, P	H, P	H, P		
	Hunting	food, trapping, archery, wading/water contact		H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
	Plants	food, medicinal, hand gathering/ digging, wading/water contact					H,E	H,E	H,E			H, E	H, E		
Utilitarian (CUL-1, CUL-2)	Washing	personal hygene, dish and clothes washing, wading/water contact	Ingestion, inhalation, dermal absorption	H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
	Plants	dyes, fish/hunt materials, basketry, wading/water contact		H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
	Rocks	homes, art, weapons, cooking, wading/water contact		H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
	Cooking	boiling/rinsing/drinking, wading/water contact		H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
	Fish and Wildlife	regalia, clothing, tools, wading/water contact		H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
Recreation (REC-1, REC-2, NAV)	Boating	travel, wading/water contact, drinking	Ingestion, dermal absorption	H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E
	Swimming	wading/water contact, submersion, drinking						H,E	H,E	H, E	H, E	H, E			
	Trails	travel, hunting/trapping/fishing, wading/water contact, drinking		H, E	H, E	H,E	H,E	H,E	H,E	H, E	H, E	H, E	H, E	H, E	H, E

*Some ceremonies do not occur every year. Additionally, some ceremonies or parts of ceremonies currently do not occur (but may again the future) because it is unsafe to drink water from the mainstem Klamath River and dams prevent salmon from migrating into the Upper Klamath Basin.

SECTION 4.0 WATER QUALITY OBJECTIVES

The federal Clean Water Act (33 U.S.C. § 303) requires authorized tribes to submit to the Administrator of the U.S. Environmental Protection Agency for approval all new or revised water quality standards. Under federal terminology, water quality standards consist of the designated uses enumerated in Table 1 for the trust lands and the water quality objectives contained in this section. The water quality objectives contained herein are designed to satisfy all tribal and federal requirements.

As new information becomes available, the Department of Natural Resources will review the appropriateness of the objectives contained herein, and revise them if warranted. These objectives will be subject to public hearing at least once during each three-year period following adoption of water quality standards to determine the need for review and modification as appropriate.

The water quality objectives contained herein are a compilation of objectives adopted by the Karuk Tribe. Other water quality objectives and policies within the Klamath basin may apply. Whenever several different objectives exist for the same water quality parameter, the most stringent objective applies.

Controllable water quality factors shall conform to the water quality objectives contained herein. When uncontrollable factors result in the degradation of water quality beyond the levels or limits established herein as water quality objectives, then controllable factors shall not cause further degradation of water quality. Controllable water quality factors are those actions, conditions, or circumstances resulting from man's activities that may influence the quality of the waterbodies of the tribe and that may be reasonably controlled.

Water quality objectives form the basis for establishment of waste discharge requirements, waste discharge prohibitions, or maximum acceptable cleanup standards for all individuals and dischargers. These water quality objectives are considered to be necessary to protect those existing and potential future designated uses listed in Table 1 for the trust lands and to protect existing high quality waters of the Tribal waterbodies. These objectives will be achieved primarily through the establishment of waste discharge requirements for national pollutant discharge elimination system (NPDES) discharges and best management practices (BMPs) for non-point source discharges. Included as a BMP is the use of prevention through prohibitions.

The EPA, in setting waste discharge requirements, will consider, among other things, the potential impact on designated uses within the area of influence of the discharge, the existing quality of receiving waters, and the appropriate water quality objectives. EPA will make a finding as to the designated uses to be protected within the area of influence of the discharge and establish waste discharge requirements to protect those uses and to meet water quality objectives.

4.1 General Objective for All Waterbodies

The following objective shall apply to all Tribal waterbodies: *Whenever the existing quality of water is better than the water quality objectives established herein, such existing quality shall be maintained unless otherwise provided by the provisions of tribal law.*

4.2 Objectives for Surface Waters

In addition to the General Objective, the specific objectives contained in Tables 3 through 11 and the following objectives shall apply for surface waters. These objectives apply to the maximum extent allowed by law. To the extent that the Karuk Tribe lacks jurisdiction, the objectives are extended as a recommendation to the applicable regulatory authority

Ammonia

The ammonia objective applies to water designated Aquaculture (AQUA); Cold Freshwater Habitat (COLD); Rare, Threatened, or Endangered Species (RARE); Spawning, Reproduction, and/or Early Development (SPWN); and Warm Freshwater Habitat (WARM). The ammonia objective varies according to the temperature (T) and the pH of the waterbody, in addition to the presence or absence of salmonids in the genus *Oncorhynchus* (i.e., Pacific salmon and rainbow/steelhead trout):

Acute criterion:
The one-hour average concentration of total ammonia nitrogen (in mg TAN/L) is not to exceed, more than once every three years on the average, the CMC (acute criterion magnitude) calculated using the following equations:

Where salmonids in the genus *Oncorhynchus* are present:

$$CMC = MIN\left(\left(\frac{0.275}{1+10^{7.204-pH}}+\frac{39.0}{1+10^{pH-7.204}}\right),\right.$$

$$\left.\left(0.7249\times\left(\frac{0.0114}{1+10^{7.204-pH}}+\frac{1.6181}{1+10^{pH-7.204}}\right)\times\left(23.12\times 10^{0.036\times(20-T)}\right)\right)\right)$$

Where salmonids in the genus *Oncorhynchus* are absent:

$$CMC = 0.7249\times\frac{0.0114}{1+10^{7.204-pH}}+\frac{1.6181}{1+10^{pH-7.204}}\times MIN\left(51.93, 23.12\times 10^{0.036\times(20-T)}\right)$$

Chronic criterion:
The thirty-day rolling average concentration of total ammonia nitrogen (in mg TAN/L) is not to exceed, more than once every three years on the average, the chronic criterion magnitude (CCC) calculated using the following equation:

$$CCC = 0.8876\times\left(\frac{0.0278}{1+10^{7.688-pH}}+\frac{1.1994}{1+10^{pH-7.688}}\right)\times\left(2.126\times 10^{0.028\times(20-MAX(T,7))}\right)$$

In addition, the highest four-day average within the 30-day averaging period should not be more than 2.5 times the CCC (e.g., 2.5 x 1.9 mg TAN/L at pH 7 and 20°C or 4.8 mg TAN/L) more than once in three years on average.

Based on the equations above, tables providing the temperature and pH-dependent values for the CMC and CCC are included as Appendix A.

Bacteria

The bacteriological quality of Tribal waters shall not be degraded beyond natural background levels. In no case shall fecal coliform, *E. coli* or *enterococci* concentrations in Tribal waters exceed the following:

In waters designated municipal and domestic supply (MUN) the median fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed 1 CFU/100 mL at the drinking source.

In waters designated for cultural contact water (CUL-1) and contact recreation (REC-1):
1. The geometric mean of *E. coli* or *enterococci* concentration shall not exceed 100 or 30 cfu/mL, respectively, in any 30 day period, nor shall the statistical threshold value (STV) of *E.coli* or *enterococci* concentration exceed 320 or 100 CFU/mL, respectively, in any 30 day period.
2. The median fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed 50/100 ml, nor shall more than ten percent of total samples during any 30-day period exceed 400/100 ml
At all areas where shellfish may be harvested for human consumption (SHELL), the fecal coliform concentration throughout the water column shall not exceed 43/100 ml for a 5-tube decimal dilution test or 49/100 ml when a three-tube decimal dilution test is used (National Shellfish Sanitation Program, Manual of Operation).

In waters designated for cultural non-contact water (CUL-2) and non-contact water recreation (REC-2), the median fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed 1000 CFU/100 mL, nor shall more than ten percent of total samples during any 30-day period exceed 2000 CFU/100 mL.

Biostimulatory Substances

Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

Copper

The concentration of dissolved copper is not to exceed, more than once every three years on the average, the site-specific and season-specific values in Table 3.

Table 3 Site-specific and season-specific criteria for dissolved copper.

Location	Criterion Maximum Concentration (CMC) (ug/L)				Criterion Continuous Concentration (CCC) (ug/L)			
	Winter (Jan-Mar)	Spring (Apr-Jun)	Summer (Jul-Sep)	Fall (Oct-Dec)	Winter (Jan-Mar)	Spring (Apr-Jun)	Summer (Jul-Sep)	Fall (Oct-Dec)
Klamath R.: Near Doggett Cr to Scott R.	17.6	22.1	25.6	15.3	10.9	13.7	15.9	9.5
Klamath R.: Scott R. to Happy Camp	12.8	13.9	18.6	22.2	7.9	8.6	11.5	13.8
Klamath R.: Happy Camp to Orleans	6.4	8.1	9.7	11.7	4.0	5.1	6.0	7.3
Salmon R. and tributaries	2.5	3.4	2.8	2.4	1.6	2.1	1.7	1.5
Tributaries to Scott R.	7.5	7.9	7.1	5.8	4.6	4.9	4.4	3.6
Tributaries to Shasta R.	19.1	45.0	50.5	14.3	11.9	28.0	31.4	8.9
All other streams	2.5	3.4	2.8	2.4	1.6	2.1	1.7	1.5

Cyanobacterial toxins and cyanobacteria cell density

Concentrations of cyanobacteria (blue-green algae) cells and cyanobacterial toxins shall conform to the limits listed in Table 4.

Table 4 Cyanobacterial toxin and cell density criteria.

Parameter	Designated Uses	Standard	Rationale for Standard
Microcystis aeruginosa cell density	Drinking water (MUN)	**Below detection**	The Minnesota (2012a, 2012b) Heinze-based BMDL short-term non-cancer "Health Based Value" of 0.04 µg/L essentially does not allow for the detection of any cells.
	Contact: Cultural (CUL-1)) Recreational ((REC-1)	**<1,000 cells/mL:** Initial media outreach and general informational signage. Begin routine monitoring.	Cell density corresponding to OEHHA "Action Level"
		<5,000 cells/mL: *Additional Media outreach and specific public health postings that warning against water contact due to levels that are 5x the OEHHA "action level"*	Cell density corresponding to 5x OEHHA "Action Level"
		<10,000 cells/mL: Repeat Media outreach and specific public health postings warning against water contact due to levels that are 10x the OEHHA "action level"	Cell density corresponding to 10x OEHHA "Action Level"
Total microcystin toxin concentration[1]	Drinking water (MUN)	**<0.04 µg/L total microcystins**[2]	Minnesota (2012a, 2012b) Heinze-based BMDL short-term non-cancer "Health Based Value" of 0.04 µg/L.
	Contact: Cultural (CUL-1) Recreational (REC-1)	**<0.8 mg/L total microcystin**: Initial media outreach and general informational signage. Begin routine monitoring.	OEHHA "Action Level"
		<4.0 mg/L total microcystin: *Additional Media outreach and specific public health postings that warn against water contact due to levels that are 5x the OEHHA "action level"*	5x OEHHA "Action Level"
		<8.0 mg/L total microcystin: Repeat Media outreach and specific public health postings warning against water contact due to levels that are 10x the OEHHA "action level"	10x OEHHA "Action Level"
Total potentially toxigenic blue-green algal species[3]	Contact: Cultural (CUL-1) Recreational (REC-1)	**<100,000 cells/mL or cyanobacterial scums**	WHO/SWRCB guidelines
Anatoxin-a	Contact: Cultural (CUL-1) Recreational (REC-1)	**<90 µg/L**	OEHHA (2012)
Cyanotoxins in Fish/Shellfish	Shellfish Harvest (SHELL), Fish Consumption, FC)	**<10 ng/g microcystins, <5000 ng/g anatoxin, <4 ng/g cylindrospermopsin** (wet weight)	OEHHA (2012)

[1] While there are numerous congeners of microcystin (e.g., microcystin-LA, RR, and YR) the most extensive toxicological information is available for the microcystin-LR congener. However, the literature indicates that most of these congeners appear to have similar toxicological effects (OEHHA 2012). Therefore, the toxicity criteria apply to the total of all microcystin congeners (if measured separately the concentration of the various congeners is summed), or if ELISA methodology is used then the reported value is already assumed to represent the total.
[2] Value based on the older WHO studies, and although OEHHA (2012) did not evaluate drinking water "action levels", the Minnesota Department of Health (2012) utilized the same Heinze-based BMDL of 0.0064 mg/kg/day that OEHHA used to arrive at a short-term non-cancer "Health Based Value" of 0.04 µg/L.
[3] Includes: *Anabaena, Microcystis*, *Planktothrix, Gloeotrichia* and *Oscillatoria*

Chemical Constituents

Waters designated for use as domestic or municipal supply (MUN) shall not contain concentrations of chemical constituents in excess of the limits listed in Table 10 and Table 11.

Waters designated for use as agricultural supply (AGR) shall not contain concentrations of chemical constituents in amounts which adversely affect such beneficial use.

Numerical water quality objectives for individual waters are contained in Table 6.

Color

Waters shall be free of coloration that causes nuisance or adversely affects beneficial uses.

Dissolved Oxygen

Dissolved oxygen concentrations shall conform to those limits listed in Table 6 and Table 7. For waters not listed in Table 6 and Table 7 and where dissolved oxygen objectives are not prescribed the dissolved oxygen concentrations shall not be reduced below the following minimum levels at any time.

Waters designated WARM	5.0 mg/L
Waters designated COLD	6.0 mg/L
Waters designated SPWN	7.0 mg/L
Waters designated SPWN during critical spawning and egg incubation periods	9.0 mg/L

Floating Material

Waters shall not contain floating material, including solids, liquids, foams, and scum, in concentrations that cause nuisance or adversely affect beneficial uses.

Nutrients and Organic Matter

Nutrients and organic matter shall conform to those limits listed in Table 8.

Oil and Grease

Waters shall not contain oils, greases, waxes, or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses.

Pesticides

No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. There shall be no bioaccumulation of pesticide concentrations found in bottom sediments or aquatic life.

Waters designated for use as domestic or municipal supply shall not contain concentrations of pesticides in excess of the limiting concentrations listed in Table 10. Waters designated Aquaculture (AQUA); Cold Freshwater Habitat (COLD); Rare, Threatened, or Endangered Species (RARE); Spawning, Reproduction, and/or Early Development (SPWN); and Warm Freshwater

Habitat (WARM) shall not contain concentrations of pesticides in excess of the limiting concentrations listed in Table 9.

pH

The pH shall conform to those limits listed in Table 6. For waters not listed in Table 6 and where pH objectives are not prescribed, the pH shall not be depressed below 6.5 nor raised above 8.5.Changes in normal ambient pH levels shall not exceed 0.5 units within the range specified above in fresh waters with designated COLD or WARM beneficial uses.

Radioactivity

Radionuclides shall not be present in concentrations which are deleterious to human, plant, animal or aquatic life nor which result in the accumulation of radionuclides in the food web to an extent which presents a hazard to human, plant, animal, or indigenous aquatic life.
Waters designated for use as municipal and domestic supply (MUN) shall not contain concentrations of radionuclides in excess of the limits listed in Table 11.

Riparian Area

Degradation shall not occur that adversely affects riparian areas which are critical to protecting the quality of a river, lake, or tributary.

Sediment

The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

Settleable Material

Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses.

Suspended Material

Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.

Tastes and Odors

Waters shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to fish flesh or other edible products of aquatic origin, or that cause nuisance or adversely affect beneficial uses.

Numeric water quality objectives with regards to taste and odor thresholds have been developed by the EPA. These numeric objectives, as well as those available in the technical literature, are incorporated into waste discharge requirements and cleanup and abatement orders as appropriate.

Temperature

The natural receiving water temperatures shall not be altered unless it can be demonstrated to the satisfaction of the Department of Natural Resources that such alteration in temperature does not adversely affect beneficial uses.

At no time or place shall the temperature of any cold freshwater habitat (COLD) water be increased by more than 2.8°C above natural receiving water temperature.

The seven-day average of daily maximum (7DADM) ambient water temperatures shall conform to the limits listed in Table 3, year-round. These objectives are for ambient water temperatures that represent the main portion of flow and therefore cannot be solely met by presence of localized cold water refugia.

In addition, in all flowing waterbodies during the September-June period of salmonid spawning and incubation, 7DADM temperatures shall not exceed 13°C (55°F).

Table 5 Year-round water temperature objectives for Tribal waterbodies.

Waterbody	Salmonid Uses During Summer Maximum Temperature Conditions	Ambient Temperature Objective (7DADM[1])
Klamath River	Salmon and trout rearing and migration	18°C (64°F)
Salmon River	Salmon and trout rearing and migration	18°C (64°F)
All other streams	Core cold water rearing[2]	16°C (61°F)

Table notes:
[1] 7DADM = Seven-day average of daily maximum temperatures
[2] The use of the phrase "Core cold water rearing" for "All other streams" is not intended to suggest that Klamath and Salmon rivers lack the potential to provide critically important salmonid rearing habitats during the summer months. The difference in designation here only reflects the understanding that large rivers are naturally expected to be warmer than smaller streams in the summer, due to the longer distance along which the water has been exposed to warming.

Toxicity

All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life. Compliance with this objective will be determined by use of indicator organisms for acute and chronic toxicity testing, analyses of species diversity, population density, growth anomalies, bioassays of appropriate duration, or other appropriate methods as specified by the Department of Natural Resources.

The survival of aquatic life in surface waters subjected to a waste discharge, or other controllable water quality factors, shall not be less than that for the same water body in areas unaffected by the waste discharge, or when necessary for other control water that is consistent with the requirements for "experimental water" as described in *Standard Methods for the Examination of Water and Wastewater*, 20th Edition (1998). As a minimum, compliance with this objective as stated in the previous sentence shall be evaluated with a 96-hour bioassay.

In addition, effluent limits based upon acute bioassays of effluents will be prescribed. Where appropriate, additional numerical receiving water objectives for specific toxicants will be established as sufficient data become available, and source control of toxic substances will be encouraged.

Turbidity

Turbidity shall not be increased more than 20 percent above naturally occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.

Table 6 Specific water quality objectives for Tribal waterbodies

Hydrologic Area	Waterbody	Specific Conductance (micromhos) @ 25 °C		Dissolved Oxygen (mg/L)[4]		Hydrogen Ion (pH units)[5]		Hardness (mg/L as $CaCO_3$)	Boron (mg/L as B)	
		90% Upper Limit[1]	50% Upper Limit[2]	Min	50% Lower Limit[2]	Max	Min	50% Upper Limit[2]	90% Upper Limit[1]	50% Upper Limit[2]
Shasta Valley	All Streams	700	400	7	9	8.5	7	200	0.5	0.1
	Groundwaters[3]	800	500	-	-	8.5	7	180	1	0.3
Scott Valley	All Streams	400	275	7	9	8.5	7	120	0.2	0.1
	Groundwaters[3]	500	250	-	-	8.0	7	120	0.1	0.1
Salmon River	All Streams	150	125	9	10	8.5	7	60	0.1	0
Middle Klamath River	Klamath R (near Doggett Creek to Orleans)	350	275	[4]	[4]	8.5	7	80	0.5	0.2
	Other Streams	300	150	7	9	8.5	7	60	0.1	0
	Groundwaters[3]	750	600	-	-	8.5	7.5	200	0.3	0.1

[1] 90% upper and lower limits represent the 90 percentile values for a calendar year. 90% or more of the values must be less than or equal to an upper limit and greater than or equal to a lower limit.

[2] 50% upper and lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be less than or equal to an upper limit and greater than or equal to a lower limit.

[3] Value may vary depending on the aquifer being sampled. This value is the result of sampling over time, and as pumped, from more than one aquifer.

[4] The Site Specific Objectives (SSOs) for dissolved oxygen (DO) for the mainstem Klamath River are presented separately in Table 7.

Table 7 Dissolved oxygen objectives for the mainstem Klamath River

Location	Percent DO Saturation Based On Natural Receiving Water Temperatures[2]	Time Period
Klamath River from near Doggett Creek to the Scott River	90%	October 1 through March 31
	85%	April 1 through September 30
Klamath River from Scott River to Orleans	90%	Year round

[1] Corresponding DO concentrations are calculated as daily minima, based on site-specific barometric pressure, site-specific salinity, and natural receiving water temperatures as estimated by the T1BSR run of the Klamath TMDL model and described in Tetra Tech, December 23, 2009, Modeling Scenarios: Klamath River Model for TMDL Development. The estimates of natural receiving water temperatures used in these calculations may be updated as new data or method(s) become available.

Table 8 Nutrient and organic Matter objectives for tribal waterbodies. TP = Total Phosphorus (units: mg/L as P), TN = Total Nitrogen (units: mg/L as N), $CBOD_5$ = Carbonaceous Biochemical Oxygen Demand.

Location	Parameter	Mean Concentration (mg/L) for Time Period														
		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Dry season: May – Oct	Wet season: Nov – Apr	Annual
Klamath R.: Near Doggett Cr to Scott R	TP	0.032	0.029	0.029	0.027	0.028	0.029	0.032	0.033	0.029	0.031	0.032	0.033			
	TN	0.327	0.247	0.217	0.221	0.245	0.275	0.299	0.328	0.270	0.334	0.340	0.333			
	$CBOD_5$	2	2	2	2	2	2	1	2	2	3	3	2			
Klamath R.: Scott R to Happy Camp	TP	0.029	0.027	0.027	0.025	0.027	0.029	0.030	0.031	0.024	0.026	0.027	0.027			
	TN	0.299	0.246	0.208	0.208	0.237	0.270	0.289	0.307	0.245	0.294	0.307	0.305			
	$CBOD_5$	3	2	2	2	2	2	1	2	2	2	3	3			
Klamath R.: Happy Camp to Orleans	TP	0.023	0.022	0.022	0.022	0.024	0.026	0.027	0.026	0.021	0.022	0.023	0.023			
	TN	0.229	0.207	0.182	0.184	0.212	0.242	0.241	0.233	0.173	0.198	0.218	0.221			
	$CBOD_5$	2	2	2	2	2	1	1	1	1	2	2	2			
Shasta River	TP													0.071	0.071	
	TN													0.210	0.210	
	$CBOD_5$													2	2	
Scott River	TP													0.028	0.019	
	TN													0.310	0.325	
	$CBOD_5$													4	3	
Salmon River	TP													0.018	0.028	
	TN													0.229	0.194	
	$CBOD_5$													2	2	
Other tributaries to Klamath River	TP															0.014
	TN															0.077
	$CBOD_5$															1

Table 9 Water quality objectives for aquatic life & organism consumption.

#	Priority Pollutant	CAS Number	Freshwater:		Human Health for the consumption of:	
			CMC (chronic) (µg/L)	CMC (acute) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
1	Antimony	7440360			5.6 B	640 B
2	Arsenic	7440382	340 A,D,K	150 A,D,K	0.018 C,S	0.14 C, S
3	Beryllium	7440417			Z	
4	Cadmium	7440439	2 D,E,K	0.25 D,E,K	Z	
5a	Chromium (III)	16065831	570 D,E,K	74 D,E,K	Z Total	
5b	Chromium (VI)	18540299	16 D,K	11 D,K	Z Total	
6	Copper	7440508	See site-specific criteria above		1300 U	
7	Lead	7439921	65 D,E	2.5 D,E		
8a	Mercury	7439976	1.4 D,K	0.77 D,K		
8b	Methylmercury	22967926				0.3 mg/kg J
9	Nickel	7440020	470 D,E,K	52 D,E,K	610 B	4600 B
10	Selenium	7782492	L, T	5 T	170 Z	4200
11	Silver	7440224	3.2 D,E,G			
12	Thallium	7440280			0.24	0.47
13	Zinc	7440666	120 D,E,K	120 D,E,K	7400 U	26000 U
14	Cyanide	57125	22 K,Q	5.2 K,Q	140 jj	140 jj
15	Asbestos	1332214			7 million fibers/L I	
16	2,3,7,8-TCDD (Dioxin)	1746016			0.000000005 C	0.0000000051 C
17	Acrolein	107028	3	3	6 ll	9 ll
18	Acrylonitrile	107131			0.051 B,C	0.25 B,C
19	Benzene	71432			2.2 B,C	51 B,C
20	Bromoform	75252			4.3 B,C	140 B,C
21	Carbon Tetrachloride	56235			0.23 B,C	1.6 B,C
22	Chlorobenzene	108907			130 Z,U	1600 U
23	Chlorodibromomethane	124481			0.4 B,C	13 B,C
24	Chloroethane	75003				
25	2-Chloroethylvinyl Ether	110758				
26	Chloroform	67663			5.7 C	470 C
27	Dichlorobromomethane	75274			0.55 B,C	17 B,C
28	1,1-Dichloroethane	75343				
29	1,2-Dichloroethane	107062			0.38 B,C	37 B,C
30	1,1-Dichloroethylene	75354			330	7,100
31	1,2-Dichloropropane	78875			0.5 B,C	15 B,C
32	1,3-Dichloropropene	542756			0.34 C	21 C
33	Ethylbenzene	100414			530	2,100

#	Priority Pollutant	CAS Number	Freshwater:		Human Health for the consumption of:	
			CMC (chronic) (µg/L)	CMC (acute) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
34	Methyl Bromide	74839			47 B	1500 B
35	Methyl Chloride	74873				
36	Methylene Chloride	75092			4.6 B,C	590 B,C
37	1,1,2,2-Tetrachloroethane	79345			0.17 B,C	4 B,C
38	Tetrachloroethylene	127184			0.69 C	3.3 C
39	Toluene	108883			1,300 Z	15,000
40	1,2-Trans-Dichloroethylene	156605			140 Z	10,000
41	1,1,1-Trichloroethane	71556			Z	
42	1,1,2-Trichloroethane	79005			0.59 B,C	16 B,C
43	Trichloroethylene	79016			2.5 C	30 C
44	Vinyl Chloride	75014			0.025 C,kk	2.4 C,kk
45	2-Chlorophenol	95578			81 B,U	150 B,U
46	2,4-Dichlorophenol	120832			77 B,U	290 B,U
47	2,4-Dimethylphenol	105679			380 B	850 B,U
48	2-Methyl-4,6Dinitrophenol	534521			13	280
49	2,4-Dinitrophenol	51285			69 B	5,300 B
50	2-Nitrophenol	88755				
51	4-Nitrophenol	100027				
52	3-Methyl-4-Chlorophenol	59507			U	U
53	Pentachlorophenol	87865	19 F,K	15 F,K	0.27 B,C	3 B,C
54	Phenol	108952			10000 ll,U	860000 ll,U
55	2,4,6-Trichlorophenol	88062			1.4 B,C	2.4 B,C,U
56	Acenaphthene	83329			670 B,U	990 B,U
57	Acenaphthylene	208968				
58	Anthracene	120127			8300 B	40,000 B
59	Benzidine	92875			0.000086 B,C	0.0002 B,C
60	Benzo(a) Anthracene	56553			0.0038 B,C	0.018 B,C
61	Benzo(a) Pyrene	50328			0.0038 B,C	0.018 B,C
62	Benzo(b) Fluoranthene	205992			0.0038 B,C	0.018 B,C
63	Benzo(ghi) Perylene	191242				
64	Benzo(k) Fluoranthene	207089			0.0038 B,C	0.018 B,C
65	Bis(2-Chloroethoxy) Methane	111911				
66	Bis(2-Chloroethyl) Ether	111444			0.03 B,C	0.53 B,C
67	Bis(2-Chloroisopropyl) Ether	108601			1400 B	65000 B

#	Priority Pollutant	CAS Number	Freshwater:		Human Health for the consumption of:	
			CMC (chronic) (µg/L)	CMC (acute) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
68	Bis(2-Ethylhexyl) Phthalate	117817			1.2 B,C	2.2 B,C
69	4-Bromophenyl Phenyl Ether	101553				
70	Butylbenzyl Phthalate	85687			1500 B	1900 B
71	2-Chloronaphthalene	91587			1000 B	1600 B
72	4-Chlorophenyl Phenyl Ether	7005723				
73	Chrysene	218019			0.0038 B,C	0.018 B,C
74	Dibenzo(a,h)Anthracene	53703			0.0038 B,C	0.018 B,C
75	1,2-Dichlorobenzene	95501			420	1,300
76	1,3-Dichlorobenzene	541731			320	960
77	1,4-Dichlorobenzene	106467			63	190
78	3,3'-Dichlorobenzidine	91941			0.021 B,C	0.028 B,C
79	Diethyl Phthalate	84662			17000 B	44000 B
80	Dimethyl Phthalate	131113			270,000	1,100,000
81	Di-n-Butyl Phthalate	84742			2000 B	4500 B
82	2,4-Dinitrotoluene	121142			0.11 C	3.4 C
83	2,6-Dinitrotoluene	606202				
84	Di-n-Octyl Phthalate	117840				
85	1,2-Diphenylhydrazine	122667			0.036 B,C	0.2 B,C
86	Fluoranthene	206440			130 B	140 B
87	Fluorene	86737			1100 B	5300 B
88	Hexachlorobenzene	118741			0.00028 B,C	0.00029 B,C
89	Hexachlorobutadiene	87683			0.44 B,C	18 B,C
90	Hexachlorocyclopentadiene	77474			40 U	1100 U
91	Hexachloroethane	67721			1.4 B,C	3.3 B,C
92	Ideno(1,2,3-cd)Pyrene	193395			0.0038 B,C	0.018 B,C
93	Isophorone	78591			35 B,C	960 B,C
94	Naphthalene	91203				
95	Nitrobenzene	98953			17 B	690 B, U
96	N-Nitrosodimethylamine	62759			0.00069 B,C	3 B,C
97	N-Nitrosodi-n-Propylamine	621647			0.005 B,C	0.51 B,C
98	N-Nitrosodiphenylamine	86306			3.3 B,C	6 B,C
99	Phenanthrene	85018				
100	Pyrene	129000			830 B	4000 B
101	1,2,4-Trichlorobenzene	120821			35	70

#	Priority Pollutant	CAS Number	Freshwater:		Human Health for the consumption of:	
			CMC (chronic) (µg/L)	CMC (acute) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
102	Aldrin	309002	3 G		0.000049 B,C	0.00005 B,C
103	alpha-BHC	319846			0.0026 B,C	0.0049 B,C
104	beta-BHC	319857			0.0091 B,C	0.017 B,C
105	gamma-BHC (Lindane)	58899	0.95 K		0.98	1.8
106	delta-BHC	319868				
107	Chlordane	57749	2.4 G	0.0043 G,aa	0.0008 B,C	0.00081 B,C
108	4,4'-DDT	50293	1.1 G,ii	0.001 G,aa,ii	0.00022 B,C	0.00022 B,C
109	4,4'-DDE	72559			0.00022 B,C	0.00022 B,C
110	4,4'-DDD	72548			0.00031 B,C	0.00031 B,C
111	Dieldrin	60571	0.24 K	0.056 K	0.000052 B,C	0.000054 B,C
112	alpha-Endosulfan	959988	0.22 G,Y	0.056 G,Y	62 B	89 B
113	beta-Endosulfan	33213659	0.22 G,Y	0.056 G,Y	62 B	89 B
114	Endosulfan Sulfate	1031078			62 B	89 B
115	Endrin	72208	0.086 K	0.036 K	0.059	0.06
116	Endrin Aldehyde	7421934			0.29 B	0.3 B
117	Heptachlor	76448	0.52 G	0.0038 G,aa	0.000079 B,C	0.000079 B,C
118	Heptachlor Epoxide	1024573	0.52 G,V	0.0038 G,V,aa	0.000039 B,C	0.000039 B,C
119	Polychlorinated Biphenyls (PCBs)			0.014 N,aa	0.000064 B,C,N	0.000064 B,C,N
120	Toxaphene	8001352	0.73	0.0002 aa	0.00028 B,C	0.00028 B,C
	Carbaryl	63252	2.1	2.1		
	Alkalinity	—		20000		
	Aluminum pH 6.5 – 9.0	7429905	750 zz	87 zz		
	Barium	7440393			1,000	
	Carbaryl	63252	2.1	2.1		
	Chloride	16887006	860,000	230,000		
	Chlorine	7782505	19	11	yy	
	Chlorophenoxy Herbicide (2,4,5,-TP)	93721			10	
	Chlorophenoxy Herbicide (2,4-D)	94757			100 yy	
	Chloropyrifos	2921882	0.083	0.041		
	Demeton	8065483		0.1		
	Ether, Bis(Chloromethyl)	542881			0.0001	0.00029
	Guthion	86500		0.01		
	Hexachlorocyclo-hexane-Technical	608731			0.0123	0.0414
	Iron	7439896		1000	300	
	Malathion	121755		0.1		
	Manganese	7439965			50	100

#	Priority Pollutant	CAS Number	Freshwater:		Human Health for the consumption of:	
			CMC (chronic) (µg/L)	CMC (acute) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
	Methoxychlor	72435		0.03	100 yy	
	Mirex	2385855		0.001		
	Nitrates	14797558			10,000	
	Nitrosamines	—			0.0008	1.24
	Dinitrophenols	25550587			69	5300
	Nonylphenol	84852153	28	28		
	Nitrosodibutylamine	924163			0.0063	0.22
	Nitrosodiethylamine	55185			0.0008	1.24
	Nitrosopyrrolidine	930552			0.016	34
	Diazinon	333415	0.17	0.17		
	Parathion	56382	0.065	0.013		
	Pentachlorobenzene	608935			1.4	1.5
	Phosphorus Elemental	7723140				
	Solids Dissolved and Salinity	—	250,000			
	Sulfide-Hydrogen Sulfide	7783064		2		
	Tetrachlorobenzene,1,2,4,5	95943			0.97	1.1
	Tributyltin (TBT)	—	0.46	0.072		
	Trichlorophenol,2,4,5	95954			1800 xx	3600 xx

Footnotes to Table 9

A This water quality criterion was derived from data for arsenic (III), but is applied here to total arsenic, which might imply that arsenic (III) and arsenic (V) are equally toxic to aquatic life and that their toxicities are additive. No data are known to be available concerning whether the toxicities of the forms of arsenic to aquatic organisms are additive.

B This criterion has been revised to reflect The Environmental Protection Agency's q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of May 17, 2002. The fish tissue bioconcentration factor (BCF) from the 1980 Ambient Water Quality Criteria document was retained in each case.

C This criterion is based on carcinogenicity of 10^{-6} risk.

D Freshwater criteria for metals are expressed in terms of the dissolved metal in the water column. The water quality criteria value was calculated by using the previous 304(a) aquatic life criteria expressed in terms of total recoverable metal, and multiplying it by a conversion factor (CF). The term "Conversion Factor" (CF) represents the recommended conversion factor for converting a metal criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column. (Conversion Factors for saltwater CCCs are not currently available. Conversion factors derived for saltwater CMCs have been used for both saltwater CMCs and CCCs). See "Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria," October 1, 1993, by Martha G. Prothro, Acting Assistant Administrator for Water, available from the Water Resource center and 40CFR§131.36(b)(1). Conversion Factors applied in the table can be found in Appendix A to the Preamble-Conversion Factors for Dissolved Metals.

E The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a hardness of 100 mg/L. Criteria values for other hardness may be calculated from the following: CMC (dissolved) = $\exp\{m_A [\ln(\text{hardness})] + b_A\}$ (CF), or CCC (dissolved) = $\exp\{m_C [\ln(\text{hardness})] + b_C\}$ (CF)
and the parameters specified in Appendix B-Parameters for Calculating Freshwater Dissolved Metals Criteria That Are Hardness-Dependent.

F Freshwater aquatic life values for pentachlorophenol are expressed as a function of pH, and are calculated as follows: CMC = exp(1.005(pH)-4.869); CCC = exp(1.005(pH)-5.134). Values displayed in table correspond to a pH of 7.8.

G This Criterion is based on 304(a) aquatic life criterion issued in 1980, and was issued in one of the following documents: Aldrin/Dieldrin (EPA 440/5-80-019), Chlordane (EPA 440/5-80-027), DDT (EPA 440/5-80-038), Endosulfan (EPA 440/5-80-046), Endrin (EPA 440/5-80-047), Heptachlor (EPA 440/5-80-052), Hexachlorocyclohexane (EPA 440/5-80-054), Silver (EPA 440/5-80-071).

I This criterion for asbestos is the Maximum Contaminant Level (MCL) developed under the Safe Drinking Water Act (SDWA).

J This fish tissue residue criterion for methyl mercury is based on a total fish consumption rate of 0.0175 kg/day.

K This criterion is based on a 304(a) aquatic life criterion that was issued in the 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water, (EPA 820-B-96-001, September 1996). This value was derived using the GLI Guidelines (60 FR 15393-15399, March 23, 1995; 40CFR132 Appendix A); the difference between the 1985 Guidelines and the GLI Guidelines are explained on page iv of the 1995 Updates. None of the decisions concerning the derivation of this criterion were affected by any considerations that are specific to the Great Lakes.

L The CMC = 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 g/l and 12.82 g/l, respectively.

N This criterion applies to total pcbs, (e.g., the sum of all congener or all isomer or homolog or Aroclor analyses.)

Q This water quality criterion is expressed as g free cyanide (as CN)/L.

S This water quality criterion for arsenic refers to the inorganic form only.

T This water quality criterion for selenium is expressed in terms of total recoverable metal in the water column. It is scientifically acceptable to use the conversion factor (0.996-CMC or 0.922-CCC) that was used in the GLI to convert this to a value that is expressed in terms of dissolved metal.

U The organoleptic effect criterion is more stringent than the value for priority toxic pollutants.

V This value was derived from data for heptachlor and the criteria document provides insufficient data to estimate the relative toxicities of heptachlor and heptachlor epoxide.

Y This value was derived from data for endosulfan and is most appropriately applied to the sum of alpha-endosulfan and beta-endosulfan.

Z A more stringent MCL has been issued by EPA. Refer to drinking water regulations (40 CFR 141) or Safe Drinking Water Hotline (1-800-426-4791) for values.

aa This criterion is based on a 304(a) aquatic life criterion issued in 1980 or 1986, and was issued in one of the following documents: Aldrin/Dieldrin (EPA 440/5-80-019), Chlordane (EPA 440/5-80027), DDT (EPA 440/5-80-038), Endrin (EPA 440/5-80-047), Heptachlor ((EPA 440/5-80-052), Polychlorinated biphenyls (EPA 440/5-80-068), Toxaphene (EPA 440/5-86-006). This CCC is currently based on the Final Residue Value (FRV) procedure.

ii This criterion applies to DDT and its metabolites (i.e., the total concentration of DDT and its metabolites should not exceed this value).

jj This water quality criterion is expressed as total cyanide, even though the IRIS RFD we used to derive the criterion is based on free cyanide.

kk This water quality criterion was derived using the cancer slope factor of 1.4 (LMS exposure from birth).

ll This criterion has been revised to reflect the Environmental Protection Agency's cancer slope factor (CSF) or reference dose (RfD), as contained in the Integrated Risk Information System (IRIS) as of (Final FR Notice June 10, 2009). The fish tissue bioconcentration factor (BCF) from the 1980 Ambient Water Quality Criteria document was retained in each case.

mm The available toxicity data, when evaluated using the procedures described in the “Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses” indicate that freshwater aquatic life should be protected if the 24-hour average and four-day average concentrations do not respectively exceed the acute and chronic criteria concentrations calculated by the Biotic Ligand Model.

zz The organoleptic effect criterion is more stringent than the value presented in the non-priority pollutants table.

yy A more stringent Maximum Contaminant Level (MCL) has been issued by EPA under the Safe Drinking Water Act.

zz This value for aluminum is expressed in terms of total recoverable metal in the water column.

Additional Notes on Table 9

1. Table 6 is based largely on the 2009 version of the U.S. EPA's National Recommended Water Quality Criteria (available at: http://water.epa.gov/scitech/swguidance/standards/criteria/current/upload/nrwqc-2009.pdf), since the 2009 version is provided in a more condensed format than the most current version (available at http://water.epa.gov/scitech/swguidance/standards/criteria/current). For the sake of brevity, footnotes and additional notes that are not completely relevant are not included. For pollutants for which U.S. EPA has added or modified recommended criteria since 2009 (for example, carbaryl), then the EPA's current recommended criteria was used. In the Table 6, "Priority" pollutants are numbered 1 to 120 while "Non-priority" pollutants are not numbered

2. Criteria Maximum Concentration and Criterion Continuous Concentration
The Criteria Maximum Concentration (CMC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

3. Criteria Recommendations for Priority Pollutants, Non-Priority Pollutants and Organoleptic Effects
This compilation lists all priority toxic pollutants and some non-priority toxic pollutants, and both human health effect and organoleptic effect criteria issued pursuant to CWA §304(a). Blank spaces indicate that EPA has no CWA §304(a) criteria recommendations. For a number of non-priority toxic pollutants not listed, CWA §304(a) "water + organism" human health criteria are not available, but EPA has published MCLs under the SDWA that may be used in establishing water quality standards to protect water supply designated uses. Because of variations in chemical nomenclature systems, this listing of toxic pollutants does not duplicate the listing in Appendix A of 40 CFR Part 423. Also listed are the Chemical Abstracts Service CAS registry numbers, which provide a unique identification for each chemical.

4. Calculation of Dissolved Metals Criteria

The 304(a) criteria for metals, shown as dissolved metals, are calculated in one of two ways. For freshwater metals criteria that are hardness-dependent, the dissolved metal criteria were calculated using a hardness of 100 mg/l as CaCO3 for illustrative purposes only. Freshwater metals' criteria that are not hardness-dependent are calculated by multiplying the total recoverable criteria before rounding by the appropriate conversion factors. The final dissolved metals' criteria in the table are rounded to two significant figures. Information regarding the calculation of hardness dependent conversion factors is included in footnote E above.

4a. Conversion Factors for Dissolved Metals

	Conversion factor (CF) for freshwater acute criteria	Conversion factor (CF) for freshwater chronic criteria
Arsenic	1.000	1.000
Cadmium	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]
Chromium III	0.316	0.860
Chromium VI	0.982	0.962
Lead	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]
Mercury	0.85	0.85
Nickel	0.998	0.997
Selenium	—	—
Silver	0.85	—
Zinc	0.978	0.986

4b. Parameters for Calculating Freshwater Dissolved Metals Criteria That Are Hardness-Dependent

					Freshwater Conversion Factors (CF)	
Chemical	**mA**	**bA**	**mC**	**bC**	**CMC**	**CCC**
Cadmium	1.0166	-3.924	0.7409	-4.719	1.136672-[(*ln*hardness)(0.041838)]	1.101672-[(*ln*hardness)(0.041838)]
Chromium III	0.8190	3.7256	0.8190	0.6848	0.316	0.860
Lead	1.273	-1.460	1.273	-4.705	1.46203-[(*ln*hardness)(0.145712)]	1.46203-[(*ln*hardness)(0.145712)]
Nickel	0.8460	2.255	0.8460	0.0584	0.998	0.997
Silver	1.72	-6.59	—	—	0.85	—
Zinc	0.8473	0.884	0.8473	0.884	0.978	0.986

Hardness-dependant metals' criteria may be calculated from the following:

CMC (dissolved) = exp{mA [ln(hardness)]+ bA} (CF)

CCC (dissolved) = exp{mC [ln(hardness)]+ bC} (CF)

Table 10 Inorganic, organic, and fluoride concentrations not to be exceeded in domestic or municipal supply[1]

Constituent	Limiting Concentration (mg/L) Lower	Optimum	Upper	Maximum Contaminant Level, mg/L
Fluoride [2]				
53.7 and below	0.9	1.2	1.7	2.4
53.8 to 58.3	0.8	1.1	1.5	2.2
58.4 to 63.8	0.8	1.0	1.3	2.0
63.9 to 70.6	0.7	0.9	1.2	1.8
70.7 to 79.2	0.7	0.8	1.0	1.6
79.3 to 90.5	0.6	0.7	0.8	1.4
Inorganic Chemicals				
* Aluminum				1.0
Arsenic				0.05
Barium				1.0
Cadmium				0.01
Chromium				0.05
Lead				0.05
Mercury				0.002
Nitrate-N (as NO_3)				45
Selenium				0.01
Silver				0.05
Organic Chemicals				
(a) Chlorinated Hydrocarbons				
Endrin				0.0002
Lindane				0.004
Methoxychlor				0.1
Toxaphene				0.005
(b) Chlorophenoxys				
2,4-D				0.1
2,4,5-TP (Silvex)				0.01
(c) Synthetics				
Atrazine				0.003
Bentazon				0.018
Benzene				0.001
Carbon Tetrachloride				0.0005
Carbofuran				0.018
Chlordane				0.0001

Table 10 Inorganic, organic, and fluoride concentrations not to be exceeded in domestic or municipal supply[1] (continued)

	Limiting Concentration (mg/L)			
Constituent	Lower	Optimum	Upper	Maximum Contaminant Level, mg/L
(c) Synthetics (continued)				
1,2-Dibromo-3-chloropropane				0.0002
1,4-Dichlorobenzene				0.005
1,1-Dichloroethane				0.005
1,2-Dichloroethane				0.0005
cis-1,2-Dichloroethylene				0.006
trans-1,2-Dichloroethylene				0.01
1,1-Dichloroethylene				0.006
1,2-Dichloropropane				0.005
1,3-Dichloropropene				0.0005
Di(2-ethylhexyl)phthalate				0.004
* Ethylbenzene				0.680
Ethylene Dibromide				0.00002
Glyphosate				0.7
Heptachlor				0.00001
Heptachlor epoxide				0.00001
Molinate				0.02
Monochlorobenzene				0.030
Simazine				0.010
1,1,2,2-Tetrachloroethane				0.001
Tetrachloroethylene				0.005
* Thiobencarb				0.07
1,1,1-Trichloroethane				0.200
1,1,2-Trichloroethane				0.032
Trichloroethylene				0.005
Trichlorofluoromethane				0.15
1,1,2-Trichloro-1,2,2-Trifluoroethane				1.2
Vinyl Chloride				0.0005
* Xylenes[3]				1.750

[1] The values included in this table are maximum contaminant levels for the purposes of ground water and surface water discharges and cleanup. Other water quality objectives (e.g., taste and odor thresholds or other secondary MCLs) that are more stringent may apply.

[2] Annual Average of Maximum Daily Air Temperature, °F Based on temperature data obtained for a minimum of five years. The average concentration of fluoride during any month, if added, shall not exceed the upper concentration. Naturally occurring fluoride concentration shall not exceed the maximum contaminant level.

[3] Maximum Contaminant Level is for either a single isomer or the sum of the isomers.

* Constituents marked with an * also have taste and odor thresholds that are more stringent than the MCL listed. Taste and odor thresholds have also been developed for other constituents not listed in this table.

Table 11. Radionuclide objectives for municipal and domestic supply (MUN)

Constituent	Units	Maximum Contaminant Level
Gross Alpha particle activity (including Radium-226 but excluding Radon and Uranium)	pCi/L	15
Gross Beta particle activity	pCi/L	50
Radium-226 plus Radium-228	pCi/L	5
Strontium-90	pCi/L	8
Tritium	pCi/L	20,000
Uranium	pCi/L	20

4.3 Water Quality Objectives for Ground Waters

In addition to the General Objective in Section 4.1, the following objectives shall apply for ground waters.

Tastes and Odors
Ground waters shall not contain taste- or odor-producing substances in concentrations that cause nuisance or adversely affect beneficial uses.

Numeric water quality objectives have been developed by the Karuk Tribe. These numeric objectives, as well as those available in the technical literature, are incorporated into waste discharge requirements and cleanup and abatement orders as appropriate.

Bacteria
In ground waters used for municipal and domestic supply (MUN), the median of the most probable number (MPN) of coliform organisms over any 7-day period shall be less than 1.1 MPN/100 mL, less than 1 CFU/100 mL, or absent.

Radioactivity
Ground waters used for municipal and domestic supply (MUN) shall not contain concentrations of radionuclides in excess of the limits listed in Table 11.

Chemical Constituents
Ground waters used for municipal and domestic supply (MUN) shall not contain concentrations of chemical constituents in excess of the limits listed in Table 10.

Ground waters used for agricultural supply (AGR) shall not contain concentrations of chemical constituents in amounts that adversely affect such beneficial use.

Numerical objectives for certain constituents for individual ground waters are contained in Table 6.

As part of the tribe's continuing planning process, data will be collected and numerical water quality objectives will be developed for those mineral and nutrient constituents where sufficient information is presently not available for the establishment of such objectives.

4.4 Procedures for Site Specific Modifications of the Numeric Criteria

The numeric criteria in sections 1 through 4 shall apply to all waters for which the Karuk Tribe determines that designated uses are attainable that provide for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water.

The Karuk Tribe's Director of Natural Resources may, at his discretion, modify the numeric water quality criteria in sections 4.1 through1 through 4.3 as they pertain to a specific waterbody or portion thereof.

(i) Any such modified criteria shall be based on sound scientific rationale, contain sufficient parameters or constituents, and shall protect the use that the Karuk Tribe determines is attainable.

(ii) Prior to modifying any numeric criteria in sections 4.1 through 4.3, the Karuk Tribe's Director of Natural Resources shall provide for public notice of and comment on such proposed modification. For any such proposed modification, the Karuk Tribe's Director of Natural Resources shall make available to the public an explanation of the basis for each proposed modification. This explanation shall be made available to the public not later than the date of public notice.

(iii) Nothing in this section shall limit the Karuk Tribe's Director of Natural Resources's authority to modify the numeric water quality criteria in sections 4.1 through1 through 4.3.

(iv) The Karuk Tribe's Director of Natural Resources shall maintain and make available to the public an updated list of modified criteria adopted pursuant to section 4.4.

4.5 Narrative Toxicity Criterion

The following statement is adopted as the narrative toxicity criterion:

Ground water, surface water, wetlands, and sediment shall be free from substances attributable to human-caused point source or nonpoint source discharges in amounts, concentrations, or combinations which are toxic to humans, animals, plants, or aquatic life.

4.6 Outstanding Waters

The Director of the Department of Natural Resources will use rulemaking to classify a Tribal waterbody as outstanding waters.

The Director of the Department of Natural Resources may adopt, by rule, site-specific water quality standards to maintain and protect existing water quality in outstanding waters.
Any Tribal member or reservation resident may nominate a Tribal water for classification as outstanding waters by filing a petition for rule adoption with the Department of Natural Resources. A petition for rule adoption to classify a Tribal waterbody as outstanding waters should include the following components:

- A map and a description of the Tribal waterbody
- A written statement in support of the nomination, including specific reference to the applicable criteria for outstanding waters classification

- Supporting evidence demonstrating that one or more of the applicable outstanding waters criteria has been met
- Available water quality data relevant to establishing baseline water quality of the proposed outstanding waters

The Director of the Department of Natural Resources may classify a Tribal waterbody as outstanding waters upon finding that the Tribal waterbody is an outstanding Tribal resource based upon one of the following criteria:

- The Tribal waterbody is of exceptional cultural, recreational or ecological significance because of its unique attributes including, but not limited to, those related to the cultural value, geology, flora, fauna, water quality, aesthetic value, or the wilderness characteristics of the Tribal waterbody.
- Threatened or endangered species are known to be associated with the Tribal waterbody. The existing water quality is essential to the maintenance and propagation of a threatened species and provides critical habitat for this species. Endangered or threatened species are identified in the Federally Listed Threatened and Endangered Species.

The following Tribal waterbody is classified as outstanding waters:

- Ishi Pishi Falls (Located on the Klamath River near the town of Somes Bar, California).

The specific locations of unlisted outstanding waters of cultural significance will be maintained as proprietary by the Director of the Department of Natural Resources.

The following water quality standards apply to listed and unlisted outstanding waters:

> *There shall be no degradation of water quality caused by a point or non-point source discharge. Public land managers are accountable for water quality protection. No exemption is allowed for logging or grazing as part of the accountability of public land managers for water quality protection.*

4.7 Antidegradation Policy

The purpose of the Karuk Tribe’s Antidegradation Policy is to promote the maintance and protection of existing water quality. This policy is implemented through the Karuk Tribe’s Forest Management Plan and Anti-Pollution Ordinance. The Karuk Tribe’s Director of Natural Resources will determine whether there is any degradation of water quality on a pollutant by pollutant basis using the following tiered system:

Tier 1: The level of water quality necessary to protect existing uses of Tribal waterbodies, including wetlands, will be maintained and protected. No degradation of existing water quality is permitted where the existing water quality does not meet the applicable water quality standard.

Tier 2: Where existing water quality is better than the applicable water quality standard for Tribal waterbodies, including wetlands, the existing water quality will be maintained and protected. However, the Department of Natural Resources may allow limited degradation of existing water quality provided that (1) the Karuk Tribe have held a public hearing on whether degradation should be allowed pursuant to the general public hearing procedures, and (2) the Department of Natural Resources makes all of the following findings:

- The level of water quality necessary to protect existing uses is fully protected.
- The highest statutory and regulatory requirements for all new and existing point sources as set forth in the CWA are achieved.
- All cost-effective and reasonable best management practices for nonpoint source control are implemented.
- Allowing lower water quality is necessary to accommodate important cultural, economic, or social development in the area in which the Tribal water is located.

Tier 3: Existing water quality that is classified as outstanding waters or that the Department of Natural Resources has proposed for classification as outstanding waters will be maintained and protected. The Department of Natural Resources will not allow limited degradation of outstanding waters.

Outstanding waters will be classified in a manner consistent with Section 316 of the CWA where a potential water quality impairment associated with a thermal discharge is involved.

SECTION 5.0 SECTION 401 WATER QUALITY CERTIFICATION

CWA Section 401 water quality certification delegates the Karuk Tribe the authority to grant, deny, or condition certification of federal permits or licenses. The Karuk Tribe designates the Department of Natural Resources as the lead tribal agency responsible for implementation of Section 401 Water Quality Certification for the trust land properties. Participation by the Department of Natural Resources in the Section 401 water quality certification process must be early enough for the Department of Natural Resources to be included in the development of alternatives and mitigation possibilities.

Section 401 water quality certification authority includes Federal permits, licenses, and other actions requiring NEPA compliance. Violation of water quality standards provides the basis for the Department of Natural Resources to deny or condition licenses and permits that have the potential to impact Tribal waterbodies, including upstream and upgradient sources of water quality impairment, through Section 401 water quality certification. Biological criteria are included as a tribal right to grant, deny, or condition certification.

SECTION 6.0 LABORATORY SUPPORT AND QUALITY ASSURANCE

6.1 Laboratory Support

A test result from a sample taken to determine compliance with a water quality standard is valid only if the sample has been analyzed by a laboratory that is licensed by the California State Department of Health Services or approved by the Director of the Department of Natural Resources for the analysis performed. A person conducting an analysis of a sample taken to determine compliance with a water quality standard will use an analytical method promulgated by the EPA in 40 CFR Part 136, *Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act,* or an alternative analytical method that is approved by the Director of the Department of Natural Resources.

6.2 Quality Assurance

In response to federal requirements, the Department of Natural Resources has developed a Quality Assurance Project Plan (QAPP) (Karuk Tribe 2011) to ensure that data generated from environmental measurement studies are technically sound and legally defensible. The QAPP summarizes procedures to be followed in administering federally funded programs that involve measurement of environmental parameters. The QAPP applies to special water quality studies involving surface and ground waterbodies, as well as to surveillance and compliance monitoring of discharges.

Briefly, the QAPP requires that (a) physical and professional capabilities be adequate to perform the analysis for all parameters in the sampling plan; (b) sample collection, handling, and preservation be conducted according to EPA manuals; (c) time-sensitive samples be transported and analyzed within specific holding times; (d) sample integrity be provided for a legal chain of custody of samples collected for support of enforcement actions; (e) analytical methods be in accordance with standardized methods; and (f) analytical quality control procedures be established for intra-laboratory checking of reference samples. Laboratory records, including reference sample results, are to be available for EPA review.

SECTION 7.0 IMPLEMENTATION AND ENFORCEMENT MECHANISMS

7.1 Implementation Mechanism

Implementing a Water Quality Control Plan will require a coordinated effort between the Karuk Tribe and the EPA. Water quality standards are the foundation for CWA Sections 305(b) water quality assessment reports, 401 water quality certification, and 319 nonpoint source control as described below.

Water Quality Control Plans provide the basis for conducting status and trend monitoring of Tribal waters, including wetlands. CWA Section 305(b) water quality assessment reports summarize water quality assessment information on the status and trends of Tribal waters, including wetlands.

Section 319 of the CWA requires the Karuk Tribe to complete assessments of nonpoint source (NPS) impacts to Tribal waterbodies, including wetlands, and to prepare management programs to control NPS impacts. Water Quality Control Plans form the basis for NPS assessments and management of Tribal waterbodies, including wetlands.

Section 401 water quality certification for federal permits, licenses, and other environmental actions requiring NEPA compliance. Water quality standards have the potential to be applied to other Tribal programs, including landfill sitings, game and fish management and acquisition decisions, and best management practices to control nonpoint sources of pollution.

7.2 Enforcement Mechanism

Enforcement of these water quality standards will be the duty and responsibility of the Director of the Department of Natural Resources. The Director of the Department of Natural Resources will work in cooperation with EPA, Tribal agencies, and Tribal personnel as needed to enforce the water quality standards.

To ensure compliance with the water quality standards, the Department of Natural Resources will routinely monitor and assess the quality of Tribal waterbodies. An annual water quality assessment report for Tribal waters will be prepared by April 30 for each previous calendar year. The annual water quality assessment report will be distributed to the Tribal Council, as well as other Tribal agencies as determined by the Director of the Department of Natural Resources. Copies will be made available without charge to tribal members. Copies also will be made available to the general public.

SECTION 8.0 REFERENCES CITED

Asarian, J.E. and J. Kann. 2014. Justification for Revisions Proposed for the Karuk Tribe of California's 2014 Water Quality Control Plan. Prepared by Riverbend Sciences and Aquatic Ecosystem Sciences, LLC for the Karuk Tribe of California Department of Natural Resources, Orleans, California.

Karuk Tribe. 2011. Quality Assurance Project Plan for Water Quality Sampling and Analysis. CWA 106 grant identification # BG-97991209. Prepared by Karuk Tribe Water Quality Program, Karuk Tribe Department of Natural Resources, Orleans, CA.

U.S. Environmental Protection Agency (USEPA). 2009. National Recommended Water Quality Criteria. Office of Water, Office of Science and Technology 4304T. U.S. Environmental Protection Agency, Washington, DC. 184 pp. Available online at: <http://water.epa.gov/scitech/swguidance/standards/criteria/current/upload/nrwqc-2009.pdf> accessed 12/31/2012.

APPPENDIX A: TABLES FOR AMMONIA OBJECTIVE

Based on the equations in Section 4.2, the tables on the following pages provide the temperature and pH-dependent values of the Criterion Maximum Concentration (CMC) and CCC (Criterion Continuous Concentration) for the ammonia objective.

Temperature and pH-Dependent Values of the CMC (Acute Criterion Magnitude): *Oncorhynchus* spp. Present

		Temperature °C																
		0-14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
pH	6.5	33	33	32	29	27	25	23	21	19	18	16	15	14	13	12	11	9.9
	6.6	31	31	30	28	26	24	22	20	18	17	16	14	13	12	11	10	9.5
	6.7	30	30	29	27	24	22	21	19	18	16	15	14	13	12	11	9.8	9.0
	6.8	28	28	27	25	23	21	20	18	17	15	14	13	12	11	10	9.2	8.5
	6.9	26	26	25	23	21	20	18	17	15	14	13	12	11	10	9.4	8.6	7.9
	7.0	24	24	23	21	20	18	17	15	14	13	12	11	10	9.4	8.6	8.0	7.3
	7.1	22	22	21	20	18	17	15	14	13	12	11	10	9.3	8.5	7.9	7.2	6.7
	7.2	20	20	19	18	16	15	14	13	12	11	9.8	9.1	8.3	7.7	7.1	6.5	6.0
	7.3	18	18	17	16	14	13	12	11	10	9.5	8.7	8.0	7.4	6.8	6.3	5.8	5.3
	7.4	15	15	15	14	13	12	11	9.8	9.0	8.3	7.7	7.0	6.5	6.0	5.5	5.1	4.7
	7.5	13	13	13	12	11	10	9.2	8.5	7.8	7.2	6.6	6.1	5.6	5.2	4.8	4.4	4.0
	7.6	11	11	11	10	9.3	8.6	7.9	7.3	6.7	6.2	5.7	5.2	4.8	4.4	4.1	3.8	3.5
	7.7	9.6	9.6	9.3	8.6	7.9	7.3	6.7	6.2	5.7	5.2	4.8	4.4	4.1	3.8	3.5	3.2	3.0
	7.8	8.1	8.1	7.9	7.2	6.7	6.1	5.6	5.2	4.8	4.4	4.0	3.7	3.4	3.2	2.9	2.7	2.5
	7.9	6.8	6.8	6.6	6.0	5.6	5.1	4.7	4.3	4.0	3.7	3.4	3.1	2.9	2.6	2.4	2.2	2.1
	8.0	5.6	5.6	5.4	5.0	4.6	4.2	3.9	3.6	3.3	3.0	2.8	2.6	2.4	2.2	2.0	1.9	1.7
	8.1	4.6	4.6	4.5	4.1	3.8	3.5	3.2	3.0	2.7	2.5	2.3	2.1	2.0	1.8	1.7	1.5	1.4
	8.2	3.8	3.8	3.7	3.5	3.1	2.9	2.7	2.4	2.3	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2
	8.3	3.1	3.1	3.1	2.8	2.6	2.4	2.2	2.0	1.9	1.7	1.6	1.4	1.3	1.2	1.1	1.0	0.96
	8.4	2.6	2.6	2.5	2.3	2.1	2.0	1.8	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.93	0.86	0.79
	8.5	2.1	2.1	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.1	0.98	0.90	0.83	0.77	0.71	0.65
	8.6	1.8	1.8	1.7	1.6	1.5	1.3	1.2	1.1	1.0	0.96	0.88	0.81	0.75	0.69	0.63	0.59	0.54
	8.7	1.5	1.5	1.4	1.3	1.2	1.1	1.0	0.94	0.87	0.80	0.74	0.68	0.62	0.57	0.53	0.49	0.45
	8.8	1.2	1.2	1.2	1.1	1.0	0.93	0.86	0.79	0.73	0.67	0.62	0.57	0.52	0.48	0.44	0.41	0.37
	8.9	1.0	1.0	1.0	0.93	0.85	0.79	0.72	0.67	0.61	0.56	0.52	0.48	0.44	0.40	0.37	0.34	0.32
	9.0	0.88	0.88	0.86	0.79	0.73	0.67	0.62	0.57	0.52	0.48	0.44	0.41	0.37	0.34	0.32	0.29	0.27

Temperature and pH-Dependent Values of the CMC (Acute Criterion Magnitude): *Oncorhynchus* spp. Absent

	Temperature °C																				
pH	0-10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
6.5	51	48	44	41	37	34	32	29	27	25	23	21	19	18	16	15	14	13	12	11	9.9
6.6	49	46	42	39	36	33	30	28	26	24	22	20	18	17	16	14	13	12	11	10	9.5
6.7	46	44	40	37	34	31	29	27	24	22	21	19	18	16	15	14	13	12	11	9.8	9.0
6.8	44	41	38	35	32	30	27	25	23	21	20	18	17	15	14	13	12	11	10	9.2	8.5
6.9	41	38	35	32	30	28	25	23	21	20	18	17	15	14	13	12	11	10	9.4	8.6	7.9
7.0	38	35	33	30	28	25	23	21	20	18	17	15	14	13	12	11	10	9.4	8.6	7.9	7.3
7.1	34	32	30	27	25	23	21	20	18	17	15	14	13	12	11	10	9.3	8.5	7.9	7.2	6.7
7.2	31	29	27	25	23	21	19	18	16	15	14	13	12	11	9.8	9.1	8.3	7.7	7.1	6.5	6.0
7.3	27	26	24	22	20	18	17	16	14	13	12	11	10	9.5	8.7	8.0	7.4	6.8	6.3	5.8	5.3
7.4	24	22	21	19	18	16	15	14	13	12	11	9.8	9.0	8.3	7.7	7.0	6.5	6.0	5.5	5.1	4.7
7.5	21	19	18	17	15	14	13	12	11	10	9.2	8.5	7.8	7.2	6.6	6.1	5.6	5.2	4.8	4.4	4.0
7.6	18	17	15	14	13	12	11	10	9.3	8.6	7.9	7.3	6.7	6.2	5.7	5.2	4.8	4.4	4.1	3.8	3.5
7.7	15	14	13	12	11	10	9.3	8.6	7.9	7.3	6.7	6.2	5.7	5.2	4.8	4.4	4.1	3.8	3.5	3.2	2.9
7.8	13	12	11	10	9.3	8.5	7.9	7.2	6.7	6.1	5.6	5.2	4.8	4.4	4.0	3.7	3.4	3.2	2.9	2.7	2.5
7.9	11	9.9	9.1	8.4	7.7	7.1	6.6	3.0	5.6	5.1	4.7	4.3	4.0	3.7	3.4	3.1	2.9	2.6	2.4	2.2	2.1
8.0	8.8	8.2	7.6	7.0	6.4	5.9	5.4	5.0	4.6	4.2	3.9	3.6	3.3	3.0	2.8	2.6	2.4	2.2	2.0	1.9	1.7
8.1	7.2	6.8	6.3	5.8	5.3	4.9	4.5	4.1	3.8	3.5	3.2	3.0	2.7	2.5	2.3	2.1	2.0	1.8	1.7	1.5	1.4
8.2	6.0	5.6	5.2	4.8	4.4	4.0	3.7	3.4	3.1	2.9	2.7	2.4	2.3	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2
8.3	4.9	4.6	4.3	3.9	3.6	3.3	3.1	2.8	2.6	2.4	2.2	2.0	1.9	1.7	1.6	1.4	1.3	1.2	1.1	1.0	0.96
8.4	4.1	3.8	3.5	3.2	3.0	2.7	2.5	2.3	2.1	2.0	1.8	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.93	0.86	0.79
8.5	3.3	3.1	2.9	2.7	2.4	2.3	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.1	0.98	0.90	0.83	0.77	0.71	0.65
8.6	2.8	2.6	2.4	2.2	2.0	1.9	1.7	1.6	1.5	1.3	1.2	1.1	1.0	0.96	0.88	0.81	0.75	0.69	0.63	0.58	0.54
8.7	2.3	2.2	2.0	1.8	1.7	1.6	1.4	1.3	1.2	1.1	1.0	0.94	0.87	0.80	0.74	0.68	0.62	0.57	0.53	0.49	0.45
8.8	1.9	1.8	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.93	0.86	0.79	0.73	0.67	0.62	0.57	0.52	0.48	0.44	0.41	0.37
8.9	1.6	1.5	1.4	1.3	1.2	1.1	1.0	0.93	0.85	0.79	0.72	0.67	0.61	0.56	0.52	0.48	0.44	0.40	0.37	0.34	0.32
9.0	1.4	1.3	1.2	1.1	1.0	0.93	0.86	0.79	0.73	0.67	0.62	0.57	0.52	0.48	0.44	0.41	0.37	0.34	0.32	0.29	0.27

Temperature and pH-Dependent Values of the CCC (Chronic Criterion Magnitude)

pH	Temperature °C																							
	0-7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
6.5	4.9	4.6	4.3	4.1	3.8	3.6	3.3	3.1	2.9	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.6	1.5	1.5	1.4	1.3	1.2	1.1
6.6	4.8	4.5	4.3	4.0	3.8	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1
6.7	4.8	4.5	4.2	3.9	3.7	3.5	3.2	3.0	2.8	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1
6.8	4.6	4.4	4.1	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1
6.9	4.5	4.2	4.0	3.7	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0
7.0	4.4	4.1	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	0.99
7.1	4.2	3.9	3.7	3.5	3.2	3.0	2.8	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95
7.2	4.0	3.7	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.96	0.90
7.3	3.8	3.5	3.3	3.1	2.9	2.7	2.6	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.97	0.91	0.85
7.4	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.96	0.90	0.85	0.79
7.5	3.2	3.0	2.8	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95	0.89	0.83	0.78	0.73
7.6	2.9	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.6	1.5	1.4	1.4	1.3	1.2	1.1	1.1	0.98	0.92	0.86	0.81	0.76	0.71	0.67
7.7	2.6	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	0.94	0.88	0.83	0.78	0.73	0.68	0.64	0.60
7.8	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95	0.89	0.84	0.79	0.74	0.69	0.65	0.61	0.57	0.53
7.9	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95	0.89	0.84	0.79	0.74	0.69	0.65	0.61	0.57	0.53	0.50	0.47
8.0	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	0.94	0.88	0.83	0.78	0.73	0.68	0.64	0.60	0.56	0.53	0.50	0.44	0.44	0.41
8.1	1.5	1.5	1.4	1.3	1.2	1.1	1.1	0.99	0.92	0.87	0.81	0.76	0.71	0.67	0.63	0.59	0.55	0.52	0.49	0.46	0.43	0.40	0.38	0.35
8.2	1.3	1.2	1.2	1.1	1.0	0.96	0.90	0.84	0.79	0.74	0.70	0.65	0.61	0.57	0.54	0.50	0.47	0.44	0.42	0.39	0.37	0.34	0.32	0.30
8.3	1.1	1.1	0.99	0.93	0.87	0.82	0.76	0.72	0.67	0.63	0.59	0.55	0.52	0.49	0.46	0.43	0.40	0.38	0.35	0.33	0.31	0.29	0.27	0.26
8.4	0.95	0.89	0.84	0.79	0.74	0.69	0.65	0.61	0.57	0.53	0.50	0.47	0.44	0.41	0.39	0.36	0.34	0.32	0.30	0.28	0.26	0.25	0.23	0.22
8.5	0.80	0.75	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45	0.42	0.40	0.37	0.35	0.33	0.31	0.29	0.27	0.25	0.24	0.22	0.21	0.20	0.18
8.6	0.68	0.64	0.60	0.56	0.53	0.49	0.46	0.43	0.41	0.38	0.36	0.33	0.31	0.29	0.28	0.26	0.24	0.23	0.21	0.20	0.19	0.18	0.16	0.15
8.7	0.57	0.54	0.51	0.47	0.44	0.42	0.39	0.37	0.34	0.32	0.30	0.28	0.27	0.25	0.23	0.22	0.21	0.19	0.18	0.17	0.16	0.15	0.14	0.13
8.8	0.49	0.46	0.43	0.40	0.38	0.35	0.33	0.31	0.29	0.27	0.26	0.24	0.23	0.21	0.20	0.19	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11
8.9	0.42	0.39	0.37	0.34	0.32	0.30	0.28	0.27	0.25	0.23	0.22	0.21	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.09
9.0	0.36	0.34	0.32	0.30	0.28	0.26	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08

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February 26, 2019

Ms. Michelle Siebal
State Water Resources Control Board
Division of Water Rights – Water Quality Certification Program
P.O. Box 2000Sacramento, CA 95812-2000

File via electronic mail to WR401Program@waterboards.ca.gov

RE: Comment on dEIR for the surrender of the Lower Klamath Hydroelectric Project (FERC Project No. 14803)

Ayukii Ms. Siebal:

On September 23, 2016, PacifiCorp and the Klamath River Renewal Corporation (KRRC) filed a joint license transfer application with the Federal Energy Regulatory Commission (FERC). Pursuant to the amended KHSA, PacifiCorp and the KRRC seek to transfer the lower four dams (J.C. Boyle; Copco No. 1; Copco No. 2; and Iron Gate) to the KRRC for the purpose of decommissioning and removal.

Before FERC can accept a license surrender application, PacifiCorp and the Klamath River Renewal Corporation must obtain water quality certification under Section 401 of the Clean Water Act (33 U.S.C. § 1341) from the State Water Board. Under Section 401 conditions of a water quality certification become conditions of any federal license or permit for the project. The State Water Board is the agency authorized to issue certification of any potential discharge from an activity that requires a FERC license or amendment. The State Water Board adopted the Water Quality Control Plan for the North Coast Region (Basin Plan). The Basin Plan includes the Beneficial Uses and Water Quality Objectives necessary to protect the Beneficial Uses. Together these constitute the Water Quality Standards that must be met before the State Water Board can issue Water Quality Certification. Issuance of a water quality certification is a discretionary action subject to CEQA compliance. The State Water Board has correctly chosen to prepare an Environmental Impact Report (EIR) because there are potentially significant impacts associated with dam transfer and removal.

On December 27, 2018 the California State Water Resources Control Board issued a draft Environmental Impact Report for the surrender of the Lower Klamath Hydroelectric Project (LKHP). Under the California Environmental Quality Act (CEQA) a Lead Agency is required to solicit comments from interested parties and the public. The Karuk Tribe is submitting comments as a long-term participant in the Klamath Hydroelectric Project decommissioning process and a signatory to the amended Klamath Hydroelectric Settlement Agreement (KHSA). Our participation in this process is driven by the unequivocal fact that reduced fish populations and poor water quality are a direct result of the operation of the Klamath Hydroelectric Project. Furthermore, operation of the Klamath Hydroelectric Project has had profound negative impacts on the traditional cultural practices and the health of Karuk Tribal members.

CEQA requires a lead agency to analyze the impacts of a project as defined in the CEQA Guidelines. In the case of an existing hydroelectric project that has been in operation before the adoption of the Clean Water Act and Endangered Species Act the ongoing impacts of the project will not register as significant. While CEQA considers the existing conditions as the baseline for analysis of project impacts, the State Water Board must analyze the existing operations to determine compliance with the Clean Water Act. We assert that the LKHP has been operating in violation of the Clean Water Act, and potentially other State and Federal Laws, for decades and this must be disclosed in a discussion of the baseline conditions.

We assert that the LKHP cannot be brought into compliance with State and Federal Laws without being removed. Clearly, dam removal and the expected discharge of sediments will have an immediate negative impact on water quality downstream of the LKHP. However, the expected long-term benefits are enormous and have been thoroughly researched and described in the 2012 EIR/EIS on Klamath Facilities Removal and further expanded on in the Klamath Dam Removal Overview Report for the Secretary of Interior (October 2012). **We are pleased that in their own analysis the Board correctly concludes that the proposed project (removal of lower four dams) is superior to the six alternatives analyzed**.

We appreciate the hard work of the California Water Board, Board staff, and consultants on developing this document.

Yootva,

Russell ‘Buster’ Attebery
Chairman

External Attachments:

Karuk Water Quality Control Plan
Spring Chinook CESA Petition
Prince et al. 2017
Thompson et al. 2018
Karuk Cultural Impacts of Dam Removal
Letter to Department of Interior RE: Ruffey Rancheria 11/08/17

Karuk Tribe Comments dEIS for the surrender of the Lower Klamath Hydroelectric Project (FERC Project No. 14803)

General Comments

In general, we find that fisheries and aquatic resources were adequately addressed and therefore we have very few comments. There is very good coverage of fisheries issues and impacts to fish to the point where there is almost too much information and redundancy.

General Comment on Sediment Concentrations--The largest threat to fish described under the proposed action is suspended sediment concentrations (SSC) downstream of the dams. The document does a good job in laying out the time frames of the treat (year 1 and year 2) and scenarios base on water year types ranging from dry to wet years and the longitudinal effects from upstream reaches to downstream reaches. Given the project is located below upper Klamath Lake where water is stored and could be released to increase the flushing rate of sediments, we suggest that this could be included as an alternative. Could some volume of water be stored in UKL to be later used as a flushing flow during reservoir drawdown to increase the rate of flushing and lessen the impact to fish and decrease the duration of fish exposures to high SSC?

The document does a good job in describing fish species and utilization under current and proposed conditions and impacts. We found a few minor inaccuracies in descriptions of the Pacific Lamprey life cycle where there was no mention of the “transformer” stage or metamorphosis from ammocoetes to adults. There an assumption that lamprey juvenile out migration occurs in the spring (like salmon smolts) when SSC would be high following reservoir drawdown. This may not be accurate because outmigration trapping in the Klamath during the fall months shows that seaward migration of juvenile “transformers” occurs during the late summer and fall months. Thus, the impact to lamprey may be over stated.

Specific Comments

Section 2.6.1 Water Conflicts Timeline Page 2-21. Despite being the topic of at least 3 feature films and receiving extensive national and international media coverage, there is no mention of the coalition of Tribes, fishermen, and conservationists that protested 3 Scottish Power Shareholder meetings in Scotland (2004-2006) follow by the disruption and protest of 3 Berkshire Hathaway Meetings in Omaha NE (2008-2010). These events were clearly more influential and significant than many of the other items included in the timeline.

Additionally, despite being extensively covered by national and international media and being led in part by California Governors Schwarzenegger and Brown, there is no mention of the Klamath Hydroelectric Settlement Agreement and the Klamath Basin Restoration Agreement signed by over 40 parties in 2010. The Agreements were unprecedented in scale, scope, and bipartisan support for a Western water conflict resolution and although the agreements were not ratified by congress, they clearly led the current project under consideration.

Timeline should also include dates of dam construction and FERC license expiration.

The “Major fish die-off” of 2002 should be referred to directly as a “fish kill.” The fish did not die of old age – they were killed by anthropogenic factors including operation of the Lower Klamath Project. The CDFG report referenced here is not included in the references at end of section. Although initial reports put the body count at 33,000, later reports included the one referenced here suggest the actual total was twice that amount.

Timeline should include that in 2006, in the first proceeding of its kind under recent amendments to the Federal Power Act, an Administrative Law Judge ruled that there was indeed suitable habitat upstream of Iron Gate Dam for anadromous fishes.

2.6.4 Prior/Related Environmental Reviews Page 2-24. This section should note that the 2007 FERC EIS recommended relicensing with trap and haul; however, the fish agencies later filed mandatory terms and conditions pursuant to section 4e of the Federal Power Act mandating volitional fish passage. This mandate by the agencies was challenged in court by PacifiCorp who alleged there was no viable fish habitat upstream of the dams. In 2006, the Administrative Law Judge overseeing PacifiCorp's appeal of agency terms and conditions ruled that fish habitat does indeed exist above the dams and affirmed the agency mandates.

3.2.3 Significance Criteria Page 3-43 – The Significance Criteria includes water quality control plans for the Hoopa Valley Tribe and Yurok Tribe but not that of the Karuk Tribe. This exclusion of the Karuk Tribe continues throughout the section. The Karuk Tribe water quality control plan and our pending 'Treatment As a State' application to EPA are attached for inclusion.

Section 3.3.2.1 Aquatic Species Page 3-194 The Karuk Tribe and the Salmon River Restoration Council recently submitted a petition to list Upper Klamath Trinity River Spring Chinook salmon the California Endangered Species List. (petition attached). On February 6, 2019 the California Fish and Game Commission voted unanimously to make Upper Klamath Trinity River Spring Chinook a candidate for listing while the petition undergoes a 12-month review. Table 3.3-1 should break out Upper Klamath Trinity River Spring Chinook from the more generic Chinook salmon category.

Table 3.3-2 Misrepresents the population of wild Upper Klamath-Trinity Spring Chinook by including Trinity River spawners that are of hatchery origin. Wild Upper Klamath-Trinity Spring Chinook spawn almost exclusively in the Salmon River and South Fork Trinity Rivers and have averaged 786 individuals since 1981. See CDFW staff presentation on the petition to list Spring Chinook to the CA Fish and Game Commission on February 6, 2019 (https://videobookcase.com/california/fish-game-commission/february-6-2019-2/).

Page 3-202 Refers to Salmon River Watershed Council – should be Salmon River Restoration Council.

Page 3-204 Should refer to Prince et al. 2017 and Thompson et al. 2018 for a more robust discussion of the status of Upper Klamath-Trinity River Spring Chinook population (attached). Thompson et al. 2018 includes physical evidence of the presence of Upper Klamath-Trinity River Spring Chinook above the dams.

Section 3.12.2.1 Tribal Cultural Chronology and Ethnology P3-794 The Karuk Tribe opposes mention of Ruffey Rancheria as representing the Shasta People. The founder and namesake of the Ruffey Rancheria, Old Man Ruffey, as well as the final distributees of the Rancheria, were all Karuk Indians. The present-day descendants of Old Man Ruffey and the final distributees who qualify by blood quantum are enrolled with the Karuk Tribe. A subgroup of Shasta People recently tried to use the terminated Ruffey Rancheria to congressionally establish their own Tribe. The Karuk Tribe's challenge to this group's claim to the Ruffey Rancheria effectively killed this effort. This EIR is an inappropriate venue to re-litigate the issue therefore mention of Ruffey Rancheria should be dismissed from the document or else Karuk's communications to congress should be included herein (attached).

P3-797 1979 was not the date when the Karuk Tribe became federally recognized. In that year, the Karuk Tribe re-established a government to government relationship with the United States.

The Karuk Tribe does not view Bright (1978) as a particularly good source to describe our ethnography. Attached is an ethnographic report we developed with a detailed bibliography. We also refer you to consider the ethnographic section of the 2012 Klamath Facilities Removal EIS/EIR as a reasonable attempt to describe Karuk Ethnography. See https://klamathrestoration.gov/sites/klamathrestoration.gov/files/Additonal%20Files%20/1/Chapter%203%20-%20Affected%20Environment_Environmental%20Consequences.pdf

Section 3.12.2.2 Historic Period P3-803 The description of the 'Historic Period' is highly sanitized and offensive. Although there is reference to the growth of Euro American settlers, the document fails to mention the magnitude of the genocide waged against Indian People by those settlers. We refer you to Madley's *An American Genocide: The United States and the California Indian Catastrophe, 1846-1873*, or Lindsay's *Murder State: California's Native American Genocide, 1846-1873*.

The description of the Klamath Hydroelectric Project and the "significant role" it played in the area's economic development should also include the role it played in destroying the area's robust eco-tourism. Similarly, it should describe the preferential power rate that the California/Oregon Power Company was required to provide the Klamath Irrigation Project with was terminated in 2006.

P3-812 Klamath Cultural Riverscape The Board correctly includes a discussion of the Klamath Cultural Riverscape which provides important context for the document.

Section 3.12.5.1 Potential Impacts to Tribal Cultural Resources
Page 3-818 Mitigation Measure TCR-1 Develop and Implement a Tribal Cultural Resources Management Plan The Karuk Tribe strongly supports this measure.

Mitigation Measure TCR-2 − Develop and Implement a Looting and Vandalism Prevention Program. The Karuk Tribe strongly supports this measure.

Mitigation Measure TCR-3 − Develop and Implement Inadvertent Discovery Plan (IDP) The Karuk Tribe strongly supports this measure.

Mitigation Measure TCR-4 − Endowment for Post-Project Implementation The Karuk Tribe asserts that the construction and operation of the Klamath Hydroelectric Project has had devastating impacts on Traditional Cultural Resources (TCRs) of every Tribe in the Klamath Basin. An endowment to protect and enhance TCRs should not be limited to the TCR's in the project area, but to all TCRs impacted by the construction and/or operation and/or removal of the dams.

Mitigation Measure TCR-6 − Land Transfer Page 3-841 The Karuk Tribe tentatively agrees with the Board's interpretation of the KHSA Section 7.6.4. However, given the Board's acknowledgement that "The process for determining future land uses under KHSA Section 7.6.4 has not advanced to the point at which competing uses, financial limitations, parcel access requirements, or other constraints have become clear," and "it is too early in the process to determine the feasibility of such [a land] transfer" we see TCR-6 as overly specific and inappropriate to include as a mitigation measure.

Potential Impact 3.12-9 Klamath Cultural Riverscape Contributing Aspect –Combined effects on the Klamath River fishery of dam removal, changes in hatchery production, and increased habitat for salmonids and **3.3.2.3Habitat Attributes Expected to be Affected by the Proposed Project Page 3-247 Fish Hatcheries**

These sections presume that the impact of hatcheries on Klamath basin fisheries is positive. The Karuk Tribe urges the Board to broaden the discussion and consider peer reviewed evidence to the contrary.

Quinones et al.[1] makes a compelling argument that Iron Gate Hatchery has served to reduce native wild Chinook salmon in the Klamath Basin. Furthermore, recent studies suggest that hatchery reared salmon suffer impaired survival rates due to epigenetic factors.[2]

Potential Impact 3.20-5 Changes to or loss of river conditions that support whitewater boating While it is true that dam removal will impact the current business model associated with commercial rafting the Hell's Corner reach, changes in river conditions and the restoration of the river channel will create new runs that may be commercially viable year-round. These new runs may require a change in the business model (e.g. inflatable kayaks as opposed to guided 14-foot rafts or multi-day wilderness trips). In addition, the discussion here fails to highlight or mention how many of these 'user days' are marred by water quality impairments. This reach is commonly posted for blooms toxic blue green algae. This should be included in the discussion. The Karuk Tribe asserts that impacts to Hell's Corner are avoidable if the mitigation included assistance in re-writing existing business plans and you consider water quality improvements associated with dam removal.

Water Quality Comments

The only mitigation measure that we have questions about is the arsenic testing and remediation (WQ-3 - Monitoring and potential remediation of reservoir sediments deposited along the Middle and Lower Klamath River floodplain) (see specific comment below in 3.2.5.7)

The proposed water quality monitoring plan is inadequate. Our main concerns with the water quality monitoring plan here:

1) Add a site at Walker Bridge. There is a 60 mile gap in monitoring stations between Iron Gate Dam and Seiad Valley, and that reach of river will experience both the greatest short-term impacts and long-term changes following dam removal. A site should be added at Walker Bridge to address this concern. While it notes in the Definite Plan (Appendix B-Definite Plan Appendix M) that Walker Bridge site was dropped due to access issues, USGS staff have been working on securing a location for a Walker Bridge monitoring location.

2) Increase/adjust parameters collected for water quality monitoring. There is a substantial reduction in the number of stations and water quality parameters in the proposed water quality monitoring plan relative to the Klamath Hydroelectric Settlement Agreement (KHSA) Interim Measure 15 (IM15) monitoring program which has been collecting baseline data since 2009. Aside from the sonde and suspended sediment monitoring, the current monitoring plan only calls for total nitrogen, total phosphorous, and blue green algae speciation monthly. Monthly nutrient sampling should also include the other forms of nitrogen and phosphorous as well as dissolved carbon that are currently being collected as part of IM15. Total nitrogen and total phosphorous alone are not adequate in analyzing changes in nutrient loads from the proposed project. Phytoplankton speciation should be focused more in the seasonal growing period (May to October) rather than monthly throughout the year and should include not only speciation of microcystin-producing algae but also concentrations of microcystin. Adding sites

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[1] Quiñones, R.M., Johnson, M.L. & Moyle, P.B. Environ Biol Fish (2014) 97: 233. https://doi.org/10.1007/s10641-013-0146-2

[2] Le Luyer, J., Laportea, M., Beacham, T. D., Kaukinen, K. H., Withler, R. E., Leong, J.S., Rondeaud, E. B., Koop, B. F., & Bernatchez, L. Proceedings of the National Academy of Sciences (2017) 114 (49) 12964-12969 https://doi.org/10.1073/pnas.1711229114

at state line (Shovel Creek) and Walker Bridge will allow for a more comprehensive analysis of water quality impacts by the project.

4) Work with USGS and KRRC to ensure that enough event-based suspended sediment concentrations (SSC) samples will be collected. An adequate number of samples need to be collected to be able to combine with continuous turbidity and flow data to construct the sediment budgets that are necessary to understand the ultimate fate of reservoir sediments. Consider adding tributary sites as well (Shasta, Scott, Salmon, Trinity), particularly to aid in the development of the sediment budget.

We would also suggest that monitoring should continue for at least five years post-drawdown. The massive scale of the proposed dam removal project merits a monitoring plan sufficiently detailed that it will adequately assess the results of the project. It is our understanding that the water quality monitoring plan is still in development, and that the SWRCB will have the final word on what needs to be included. Please ensure that the monitoring plan will provide enough information to determine if the actual effects of the dam removal matched the predictions, with the ancillary benefit of using this once-in-a-lifetime opportunity to provide crucial information needed to guide long-term river management.

The Comments on Specific Details section below is organized by section and page number. It provides suggested edits to improve the EIR’s technical accuracy.

Comments on Specific Details Related to Water Quality

Similar text is often repeated on multiple pages within the DEIR. In general, our comments here specifically reference only one page (or section) but are intended to apply to multiple pages/sections if the text we reference also appears elsewhere in the DEIR.

2.7.8.7 Water Quality Monitoring and Construction BMPs

USGS did not collect sediment samples in 2017 from the reservoirs. We suggest contacting Ben Swann of CDM Smith to see which consultants to KRRC collected the samples.

Please improve the water quality monitoring plan with suggestions listed above.

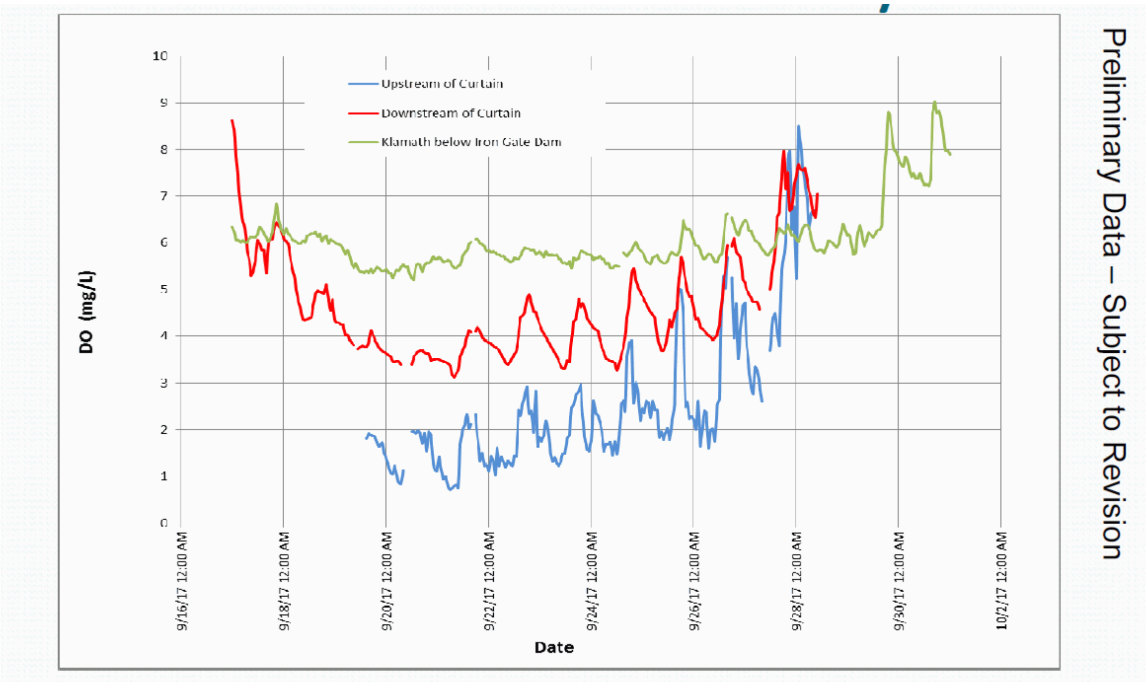
3.2 Water Quality

3.2.2 Environmental Setting

3.2.2.2 Water Temperature

Page 3-22: “The relatively shallow depth and short hydraulic residence times do not support thermal stratification in J.C. Boyle Reservoir (FERC 2007; Raymond 2008a, 2009a, 2010a) and thus this reservoir does not directly alter summertime water temperatures in further downstream reaches (NRC 2004).” We recommend adding “, other than reducing the magnitude of diel (i.e., 24-hour cycle) fluctuations” to the end of the sentence.

Page 3-23 (and also applicable to many other section of the DEIR): We recommend that any text discussing the effects of the Iron Gate Reservoir curtain should also note that during intense algae blooms the curtain has the detrimental side-effect of reducing dissolved oxygen concentrations in water released downstream. Operationally, this means that the curtain must be raised during intense blooms to avoid reducing dissolved oxygen downstream, which limits the curtain’s usefulness for reducing algae. The preliminary data in the following slide from PacifiCorp’s October 16, 2017 presentation to the Interim Measures Implementation Committee (there is not yet a draft report that includes these data) shows low dissolved oxygen values in late September 2017 downstream of the curtain (red line) and below Iron Gate Dam (green line):



Page 3-24 "Species present in the Klamath River capable of producing microcystin include *Microcystis aeruginosa* and *Anabaena flos-aquae*, while species present in the Klamath River in the genus *Anabaena* can produce anatoxin-a and saxitoxin." Other species capable of producing microcystin have been detected in the Klamath River as well (even though they never dominate). These are *Gloeotrichia* and *Planktothrix/Oscillatoria* (Genzoli and Kann 2017, E&S Environmental Chemistry, Inc. 2018, Asarian and Kann 2006). Additional potentially toxin producing genera found in the Klamath River and/or reservoirs include *Limnothrix* (E&S Environmental Chemistry, Inc. 2018) and *Pseudanabaena* (Genzoli and Kann 2017).

3.2.2.3 Suspended Sediments

Page 3-26 "However, in the summer months, organic suspended materials can increase in the Klamath River between Iron Gate Dam and Seiad Valley (RM 132.7) due to the transport of in-reservoir algal blooms to downstream reaches of Klamath River as well as resuspension of previously settled organic materials (YTEP 2005; Sinnott 2008; Armstrong and Ward 2008; Watercourse Engineering, Inc. 2011a, 2011b, 2012, 2013, 2014, 2015, 2016). Further downstream, near the confluence with the Scott River (RM 145.1) concentrations of organic suspended materials tend to decrease with distance as phytoplankton gradually settle out of the water column farther downstream or are diluted by tributary inputs (see Appendix C for more detail)." The Scott River is downstream of Seiad Valley, so it is potentially confusing to use the term "further downstream" here.

3.2.2.4 Nutrients

Page 3-28: The sentence "TP and TN concentrations in the Klamath River vary with flow, with the highest concentrations tending to occur during low flow years (e.g., 2001-2004) and the lowest concentrations tending to occur during high flow years (e.g., 2006, 2010, 2011) (Asarian and Kann 2013)" should be revised to note that it pertains only to the low-flow season (summer and early fall). TP can be very high during peak winter and spring flows due to suspended sediment.

3.2.2.7 Chlorophyll-a and Algal Toxins

Page 3-34: The sentence previous to this one "Diatoms (i.e., unicellular, photosynthetic microalgae) typically dominate in spring then decrease due to zooplankton grazing and the onset of water column stratification, which results in the diatoms settling out of the water column below the lake or reservoir surface layer (epilimnion)." refers to longitudinal trends including those for the riverine reaches, but this quoted sentence focuses on lentic (i.e., non-flowing) waters only- it should be revised to note that, since the dynamics do not apply to free-flowing river reaches.

Page 3-36: "Phycocyanin, a pigment produced by blue-green algae, has been collected between May and November at some monitoring sites in the Klamath River downstream of Iron Gate Dam since 2007. At Seiad Valley (RM 132.7), phycocyanin is typically low from May through early August, increases to a peak in early September, and decreases until reaching low levels again by the end of October (Asarian and Kann 2013). Phycocyanin concentrations generally coincide with chlorophyll-a concentrations for the portion of the Klamath River at Seiad Valley." We recommend that these sentences should be revised/replaced. Genzoli and Kann (2016) has a much more comprehensive analysis of Klamath River phycocyanin data than Asarian and Kann (2013). In addition, phycocyanin is measured by continuous probes, so it would be more accurate to say "measured" rather than "collected".

Page 3-37 The text citing the Otten et al. (2015) study should also be revised to briefly mention the genetic evidence for Iron Gate Reservoir being the source for *Microcystis* in the lower Klamath River. This genetic evidence is mentioned in section 3.4 Phytoplankton and Periphyton. Otten et al. (2015) document with genetic analysis that algal production in Iron Gate Reservoir is the principal source of *Microcystis aeruginosa* responsible for the observed public health exceedances occurring in the Klamath River downstream from Iron Gate Dam.

Page 3-37: Genzoli and Kann (2017) serves as a recent compilation of *Microcystis* and microcystin trends in the middle Klamath River, including diel, seasonal and longitudinal trends. Although this document is covered elsewhere (e.g., page 3-403; 3-414; 3-417, 3-431) it would be useful to cite here as well.

3.2.2.7 Chlorophyll-a and Algal Toxins

Page 3-38 contains the following paragraph regarding anatoxin-a:

"Anatoxin-a produced by the genus *Anabaena* of blue-green algae species was detected in Iron Gate Reservoir on September 3, 2005, in testing by the California Department of Health Services (Kann 2007a; Kann 2008b). In additional, monitoring conducted for the Karuk Tribe during 2005, 2006, 2007, 2008 in Copco No. 1 or Iron Gate reservoirs found no anatoxin-a detected (Kann and Corum 2006, 2007, 2009; Kann 2007b). At Lower Klamath River monitoring sites, anatoxin-a was not detected above the reporting limit in water samples collected during 2008 and 2009 (Fetcho 2009, 2011). In recent years, anatoxin-a has been measured in the Klamath River downstream of Iron Gate Reservoir on several occasions, typically in the lower reaches including at monitoring sites near Weitchpec and Orleans (Otten 2017). While concentrations of Anabaena flos-aquae cells have continued to be monitored, anatoxin-a concentrations are not available for Lower Klamath Project reservoir and Klamath River sites in recent years."

We recommend that this paragraph be updated to reflect more recent Klamath River data, the uncertainty in the sources of anatoxin, and the potential contribution of benthic sources (i.e. periphyton) in anatoxin-a production. The issue of potential benthic contributions to anatoxin-a production also applies to several other places within the DEIR. In our opinion, potential benthic production of anatoxin would not change any of the effects determinations in DEIR but should probably be included for the sake of completeness. Here is a replacement paragraph to consider using in place of the paragraph quoted above:

"Anatoxin-a has been detected in the Klamath River system, although the timing, distribution, and sources of anatoxin-a production in the Klamath is not well understood. Cyanobacterial species from a number of genera are capable of producing anatoxin-a, including *Dolichospermum* (planktonic species previously considered part of the genus *Anabaena* are now called *Dolichospermum*), *Anabaena* (previously included planktonic and benthic species whereas it is now only benthic species), *Aphanizomenon*, *Cylindrospermopsis*, *Planktothrix* (*Oscillatoria*), and *Phormidium* (Chorus and Bartram 1999, Quiblier et al. 2013, U.S. EPA 2014, Bouma-Gregson et al. 2018). Although toxin-producing phytoplankton are more well studied, periphyton can also produce toxins including anatoxin-a (Heath et al. 2011, Quiblier et al. 2013). In many California rivers and streams not impounded by dams, periphyton are assumed to be the primary sources Anatoxin-a (Fetscher et al. 2015), including species in genus *Anabaena* and *Phormidium* in tributaries of the Eel River located south of the Klamath River (Asarian and Higgins 2018, Bouma-Gregson et al. 2018). Anatoxin-a was detected in Iron Gate Reservoir on September 3, 2005, in testing by the California Department of Health Services (Kann 2007a; Kann 2008b), while monitoring conducted for the Karuk Tribe during 2005-2008 in Copco No. 1 and Iron Gate reservoirs did not detect anatoxin-a (Kann and Corum 2006, 2007, 2009; Kann 2007b). At Lower Klamath River monitoring sites, anatoxin-a was not detected in water samples collected during 2008 and 2009 (Fetcho 2009, 2011). In more recent years (2010, 2015, 2016), anatoxin-a was detected in the Klamath River from sites directly below Iron Gate Dam to the Klamath River Estuary (unpublished data from the Yurok and Karuk Tribes). Genetic tools that detect the presence of an anatoxin-a synthase gene came back positive for 19.5% of 123 samples from throughout the Klamath River system, although how the presence of the synthase gene relates to toxin concentrations is still unknown (Otten 2017). The detection of anatoxin-a over many years suggest that anatoxin-a poses a persistent public health threat for the Klamath River, yet the timing, spatial scale, and sources of the toxin are poorly understood due to limited monitoring for anatoxin-a."

3.2.3 Significance Criteria

3.2.3.1 Thresholds of Significance

Page 3-54: Table 3.2-7 lists the Hoopa Valley Tribe's water quality objectives that are to be used (along with the applicable objectives from the NCRWQCB and Yurok Tribe) to evaluate thresholds of significance for water quality impacts. The table has a footnote that:

'HVTEPA (2008) includes a natural conditions clause which states, "If dissolved oxygen standards are not achievable due to natural conditions, then the COLD and SPAWN standard shall instead be dissolved oxygen concentrations equivalent to 90% saturation under natural receiving water temperatures." USEPA has approved the Hoopa Valley Tribe definition of natural conditions; the provision that site-specific criteria can be set equal to natural conditions and the procedure for defining natural conditions have not been finalized as of December 2018.'

There is also a second similar footnote regarding total nitrogen and total phosphorus. While not strictly wrong, those footnotes are incomplete because they do not mention that until the Tribe establishes the procedure for defining natural conditions, and EPA approves that procedure, the natural conditions do not have any legal weight. The exact wording in EPA's Feb 14, 2008 approval letter was: "with the understanding that unless and until the Hoopa Valley Tribe completes the process of establishing Natural Condition reference conditions, the stated numerical criteria... will constitute the operative criteria for all purposes." Therefore, we recommend that "USEPA has approved the Hoopa Valley Tribe definition of natural conditions; the provision that site-specific criteria can be set equal to natural conditions and the procedure for defining natural conditions have not been finalized as of December 2018" be replaced with "USEPA has approved the Hoopa Valley Tribe definition of natural conditions with the understanding that unless and until the Hoopa Valley Tribe completes the process of establishing Natural Condition reference conditions, the stated numerical criteria will constitute the operative criteria for all purposes."

Page 3-59 and page 3-60: The overall approach for assessing the significant of impacts for nutrients makes sense, but we are unclear on why this section mentions the TMDL targets for Total Nitrogen (TN) and Total Phosphorus (TP) but not the Hoopa Valley Tribe's objectives for TN and TP?

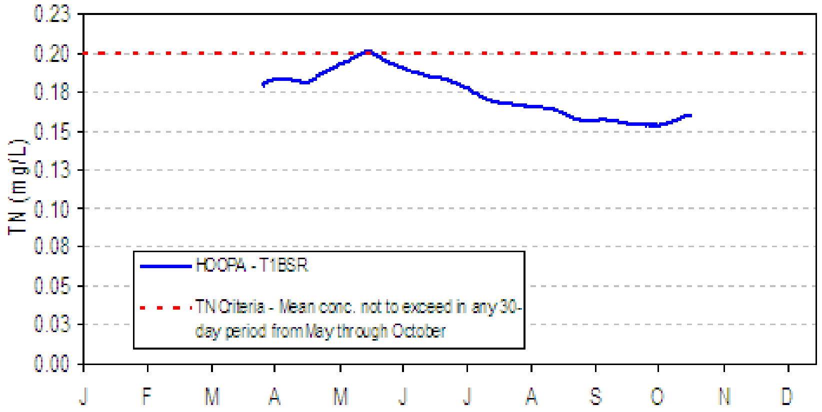
3.2.5 Potential Impacts and Mitigation

3.2.5.3 Nutrients

Page 3-117 includes the following sentence:

"Klamath River TMDL model results indicate that while resulting TP levels would meet the existing Hoopa Valley Tribe numeric water quality objective (0.035 mg/L TP) in all months at the Hoopa reach (approximately RM 45) of the Klamath River, TN levels would continue to be in excess of the existing objective (0.2 mg/L TN) in all months, as would TN levels for the modeled 'natural conditions' (T1BSR) and the modeled 'dams-in' scenario (T4BSRN) (for the months of October through June) (North Coast Regional Board 2010)."

The second half of this sentence is incorrect, so we recommend that it be revised. The TN concentrations predicted in the final version of the 'natural conditions' (T1BSR) scenario exceeded the Hoopa Valley Tribe's criteria only for a few days in May, not 'in all months'. In addition, the magnitude of the exceedance is so small that it can reasonably be considered de minimis, as shown in the following figure from the North Coast Regional Board (2010):



The incorrect statement on TN exceedances may be a result of outdated information. Initial versions of the 'natural conditions' (T1BSR) scenario did indicate substantive exceedances of the Hoopa Valley Tribe's TN objective; however, these exceedances were caused by unrealistically high TN concentrations assigned to tributaries. Once these tributary concentrations were corrected to more closely represent available data, the exceedances essentially disappeared in the final official version of the model (i.e., see figure above).

Page 3-117 "While there would be a slight increase in absolute nutrient concentrations entering the Middle Klamath River under the Proposed Project, phytoplankton, especially blue-green algae, would be limited in their ability to use those nutrients for growth and reproduction without calm reservoir habitat (Potential Impact 3.4-2)." We recognize that word choices are subjective, but "slight" is probably not the most accurate word to describe the expected increase, unless it is specifically in reference to annual time scales, not seasonal time scales. As noted on page 3-116, the increases in TN for the July through September period are expected to be in the range of 48-55%. We suggest replacing "a slight increase" with "an increase".

Page 3-118: "In general, although dam removal would result in a slight long-term increase in TP and TN away from the numeric targets, such an increase would not support the growth of nuisance and/or noxious phytoplankton or nuisance periphyton." Similar to our previous comment above regarding page 3-117, it would be more accurate to replace "a slight long-term increase in TP and TN" with "a long-term increase in TP and TN" or "a slight long-term increase in annual TP and TN".

Page 3-135: "…monitoring data at multiple locations further downstream in the Middle and Lower Klamath River indicate that pH patterns over a 24-hour period are driven primarily by photosynthesis and respiration of periphyton (Ward and Armstrong 2010; Asarian et al. 2015; see Section 3.4.2.2 Periphyton) rather than phytoplankton." A direct quantification of the relative contributions to primary production in the Middle Klamath River is provided by Genzoli and Hall (2016). Even though Genzoli and Hall's (2016) analysis did not specifically evaluate pH, we recommend that it should still be cited here.

3.2.5.5 pH

Page 3-136: "Since N-fixing species dominate the periphyton communities in the lower portions of the Middle Klamath River as well as the Lower Klamath River where inorganic nitrogen concentrations are low (Asarian et al. 2010, 2014, 2015), changes in nutrients due to dam removal are not expected to alter the periphyton community in these reaches (see Potential Impact 3.4-5)." The species composition of the periphyton community may well shift, but the biomass is not expected to increase substantially. We suggest that this end of this sentence be revised to "…are not expected to substantially alter total periphyton biomass in these reaches (see Potential Impact 3.4-5)."

3.2.5.6 Chlorophyll-a and Algal Toxins

Page 3-137. While reservoir phytoplankton are by far the dominant source of algal toxins in the Klamath River, Section 3.2.5.6 Chlorophyll-*a* and Algal Toxins should probably also mention that river periphyton are capable of producing cyanotoxins including anatoxin-*a*. This would not change the effects determinations but should be mentioned for the sake of completeness. See comments regarding page 3-38 above for details.

Page 3-138. This statement merits correction:

"While algal toxins and chlorophyll-a produced in Upper Klamath Lake may still be transported downstream after dam removal, existing data indicate that microcystin concentrations in the Klamath River decrease to below California water quality objectives (see Section 3.2.3.1 *Thresholds of Significance*) by the upstream end of J.C. Boyle Reservoir, regardless of the microcystin concentration measured leaving the Upper Klamath Lake (Watercourse Engineering, Inc. 2011a, 2011b, 2012, 2013, 2014, 2015, 2016)."

There have been high microcystin levels on occasion in JC Boyle at Topsy Campground. It is more correct to say that microcystin concentrations in the Klamath River decrease to below California water quality objectives downstream of JC Boyle. (e.g., E&S Environmental Chemistry, Inc. 2018). Then the following sentence is still correct: "Thus, algal toxins and chlorophyll-a production upstream of J.C. Boyle Dam would not be expected to be transported into California and result in algal toxin or chlorophyll-a concentrations in a manner that would cause or substantially exacerbate an exceedance of water quality standards or would result in a failure to maintain existing beneficial uses currently supported."

3.2.5.7 Inorganic and Organic Contaminants

Page 3-150: Mitigation Measure WQ-3 (Monitoring and potential remediation of reservoir sediments deposited along the Middle and Lower Klamath River floodplain) proposes that following dam removal, floodplain deposits in areas with agricultural and residential land use should be tested for arsenic and then remediated (removal or soil capping) if arsenic levels exceed background levels found in adjacent soils and USEPA or CalEPA human health residential screening levels. According to information presented on page 3-142 of the DEIR, soils in the Klamath Basin have naturally high arsenic levels, and arsenic levels in samples from reservoir sediments were within those natural ranges. Remediating arsenic-rich soils along the river corridor could be quite expensive and is not a decision to be taken lightly. Floodplains are naturally dynamic environments and healthy floodplains experience both sediment deposition and erosion. Floodplain soils are heterogeneous with deposits of varying ages and source compositions. Basing the decision about whether to remediate a particular reservoir-derived sediment deposit on a comparison to arsenic levels in adjacent soils seems subject to a high degree of uncertainty and luck of the draw (e.g. what particular portion of reservoir sediment ended up settling on top of what particular floodplain deposit). How will decisions be made about the definition “exceed” (e.g., does that mean that the average has to be 0.1% higher, or some greater threshold? What if any statistical tests will be used?) And how many samples will need to be collected and over what geographic area? There is definitely value in remediating truly contaminated soils that have arsenic concentrations substantially higher than ambient conditions, but is how will such thresholds be determined?

3.4 Phytoplankton and Periphyton

3.4.2 Environmental Setting

3.4.2.1 Phytoplankton

Page 3-397: Need to distinguish planktonic “*Anabaena”* which is now called *Dolichospermum*, from benthic forms still referred to as *Anabaena*.

3.4.2.2 Periphyton

Page 3-403: "Monitoring at multiple locations along the Middle and Lower Klamath River indicates that dissolved oxygen and pH patterns over a 24-hour period are driven primarily by photosynthesis and respiration of periphyton (Ward and Armstrong 2010, Asarian et al. 2015)." A citation of Genzoli and Hall (2016) should be added here (see comment above regarding page 3-135 for justification).

3.4.2.3 Hydroelectric Reach

Page 3-413: "Nuisance blooms of periphyton have not been documented in the riverine portions of the Hydroelectric Reach. In the J.C. Boyle Peaking Reach, it has been noted that periphyton tends to be absent from the margins of the river that are alternately dried and wetted during peaking operations (E. Asarian, pers. comm., 2011)." We recommend that the end of this sentence be re-structured with different references, so that it ends with “periphyton tends to be absent from the margins of the river that are alternately dried and wetted during peaking operations (Karuk Tribe 2006), due to reasons described by PacifiCorp (2005)”. Note that the PacifiCorp (2005) report is unavailable online but we have it in our files; please contact us if you need a copy.

3.4.5 Potential Impacts and Mitigation

3.4.5.1 Phytoplankton

Page 3-431: This sentence suggests that river growth of BGA is causing exceedances:

“Some phytoplankton growth may still occur after dam removal in calm, slow-moving habitats along shorelines and protected coves and backwaters during low-flow periods in the Middle and Lower Klamath River, but these habitats already support growth of blue-green algae, including Microcystis aeruginosa, that results in occasional exceedances of 2016 CCHAB secondary thresholds and WHO guidelines (Falconer et al. 1999; Kann et al. 2010; State Water Board et al. 2010, updated 2016; Genzoli and Kann 2016, 2017).”

It is not likely that these slow-moving and backwater areas support growth of blue-green algae, but rather are sites where upstream sources accumulate as slowed velocity allows them to settle or become trapped in vegetation. Thus the exceedances currently detected in such areas would decrease with dam removal. There is no evidence that we are aware of for actual growth of planktonic cyanobacteria in the Middle and Lower Klamath.

3.10 Greenhouse Gas Emissions

Page 3-717. This section mentions that the DEIR’s method for estimating methane emissions from Klamath Hydroelectric Project reservoirs was adapted from Karuk Tribe’s (2006) comments which multiplyied the reservoirs’ area by areal emissions rates from reservoirs around the world with similar water quality characteristics. The Karuk Tribe’s estimates were best the information available at that time, but there is now new information available including a global synthesis (Deemer et al. 2016) and field measurements of methane emissions available from J.C. Boyle Reservoir and Keno Reservoir (Harrison et al 2017) using methods from Deemer et al. (2011). We also encourage SWRCB to consider incorporating these recent studies into the EIR.

LIST OF MINOR/INSIGNIFICANT ERRORS

During our review of the DEIR we noticed a few minor/insignificant errors, which we present in this separate list to avoid cluttering our other comments.

Page 2-98: “Microcystin [-Producing Blue-green Algae] Cell Count” is odd phrasing that doesn't match the conventions used in the rest of the DEIR. Should be “Microcystin-Producing Blue-green Algae Cell Count”?

Page 3-35: The last sentence on this page references the wrong figure regarding chlorophyll-*a* (should be Figure 3.2-5, not Figure 3.2-25).

page 3-58: "the clarity or murkiness of the water cause**s** by small particles" should be "the clarity or murkiness of the water cause**d** by small particles"

Page 3-137: "Microcystis aeruginosa" should be italicized at line bottom of the page

Page 3-717: This page cites Appendix N for greenhouse gas emissions but it should actually be Appendix O instead?

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Note: only references not already included in the DEIR are included here.

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