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Determining Spatial Distribution and Habitat Use for Coho salmon (Oncorhynchus kisutch) in Hoopa Tribal Streams Using Occupancy Modeling to Inform Restoration

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ABSTRACT

Pacific salmonid populations have faced significant decline due to poor management and human disturbance. Habitat restoration and monitoring is essential to the ongoing survival of these fish. This study examines population abundance of juvenile Coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*O. tshawytscha*) and steelhead trout (*O. mykiss*) in five tributaries of the Trinity River in Northern California to determine the success of recent restoration efforts. We used traditional snorkel survey methods paired with an occupancy model to compare populations of two restored streams and four unrestored streams. We found that despite Coho being detected in all six streams, restored sites were less likely to have Coho compared to the unrestored sites. When Coho were not detected there was a high probability that the undetected fish was in fact not present in the site. We attribute these findings to the complexity of the restored streams making detection less likely, lack of riparian cover, and a low surveyor detection probability. Despite these counterintuitive findings, it is likely that as riparian vegetation matures and increases cover and shading, salmonids will use these streams in greater numbers. Our findings will aid in informing managers of how restoration decisions will affect Coho salmon populations.

INTRODUCTION

In California, significant declines in salmon and trout population have sparked concern in fisheries managers within the Klamath-Trinity River basin. Salmonid declines in different regions are caused by a host of anthropogenic impacts (Adams et al., 2011). Coho salmon (*Oncorhynchus kisutch*) are listed as threatened under both the California Endangered Species Act (CESA) and the Federal Endangered Species Act (ESA) (Chase et al., 2010). Coho, Chinook (*Oncorhynchus tshawytscha*) between the Klamath and Russian Rivers, and all steelhead (*Oncorhynchus mykiss*) south of the Klamath River are ESA listed threatened or endangered (Adams et al., 2011). The severity of declining populations in concert with CESA and ESA listings influence federal mandates for the recovery of the species in their particular population territory, known as an environmentally significant unit (ESU) (Roni & Anders, 2018). This ultimately led to the California Coastal Salmonid Monitoring Plan (CMP) (Adams et al., 2011).

Monitoring is an important component of restoration, and recovery efforts are federally mandated to include measurable criteria. When a listed species meets the set criteria, such as a population that can support recreational and commercial fishing, it can be delisted from the ESA (Adams et al., 2011). Juvenile salmonid sampling methods provide information on abundance, spatial distribution, habitat utilization, limiting factors at differing life history stages, and can distinguish ocean versus freshwater mortality (Adams et al., 2011). Knowing how these and other factors affect production at various life stages is critical in restoration geared toward juvenile salmonid production and survival: understanding of juvenile salmonid habitat requirements and limitations enables researchers and managers to implement restoration efforts focused on specific needs at targeted life histories. The CMP has four typical methods of juvenile outmigration monitoring: electrofishing, out-migrant traps (inclined plane and rotary screw traps

(RST)), and snorkel surveys (Adams et al., 2011). Tagging with acoustic tags and/or passive integrated telemetry (PIT) tags are used in outmigration surveys as well (Chase et al., 2010; CDFW, 2019). Endangered Coho salmon are especially rare and cryptic, which can lead to false non-detection (Sethi & Benolkin, 2013). During the freshwater juvenile life stage, smaller fish can be exceptionally hard to detect. Therefore, researchers need a way to identify if the target species is truly absent from the site (Sethi & Benolkin, 2013).

Occupancy models are a way to account for uncertainty in detection or non-detection when surveying fish. Typically, statistical abundance estimates rely on counts such as number of organisms observed, which can lead to two problems: 1) surveys often cannot cover the entire area of interest and instead sample survey units; this selection of small area leads to inferences of an entire area, and 2) species are not always detected on each sampling occasion even when they are present (MacKenzie et al., 2002). Imperfect detection can be amplified when a species is uncommon, so surveyors cannot truly know if a species is absent from a site or undetected (Sethi & Benolkin, 2013). To address this issue, the probability of organisms occupying a site must be modeled along with the probability of the species being detected by surveyors if the species is in fact present at the site (Sethi & Benolkin, 2013). By using occupancy models researchers can account for occupancy uncertainty at a given site.

The Trinity River, located on the North Coast of California, is a tributary to the Klamath River and home of the Hoopa Valley Tribe (Figure 1). The Trinity River flows from Lewiston Dam in Trinity County to its confluence with the Klamath River at the town of Weitchpec in Humboldt County. The 85,445 acre Hoopa Valley Reservation is the largest and most populous reservation in California. The population of 3,393 consists of Hoopa Tribal members and a mix of Karuk, Chilula, Yurok, Whilkut, and other tribal nations (U.S. Census Bureau, 2017; FNMB, 2017; Higley, 2008). The Hoopa Tribe has lived in the region since approximately 1000 AD when the tribe migrated into the region from the north (FNMB, 2017). The Hoopa Tribe signed a treaty in 1864 with the Federal Government establishing the 1,412 square mile area as the Hoopa Reservation (FNMB, 2017). The Hoopa people are a sovereign nation within their home territory, with an established government and associated services (Ortiz, 2002; Higley 2008). The Hoopa Tribal people rely on subsistence fishing of species including Pacific salmon, trout, sturgeon, and lamprey; this has sustained them for thousands of years (Lewis, 1992). The Hoopa people have a deep connection to the Trinity River and the resources the river provides (Lewis, 1992), and they have invested a considerable amount of time, energy, and resources in the preservation and protection of these culturally significant resources. The land, in the form of all resources within tribal boundaries and other culturally relevant sites, is managed by various Hoopa Valley Tribal departments. Stream resources within the boundary are managed by the Hoopa Tribal Fisheries Department.

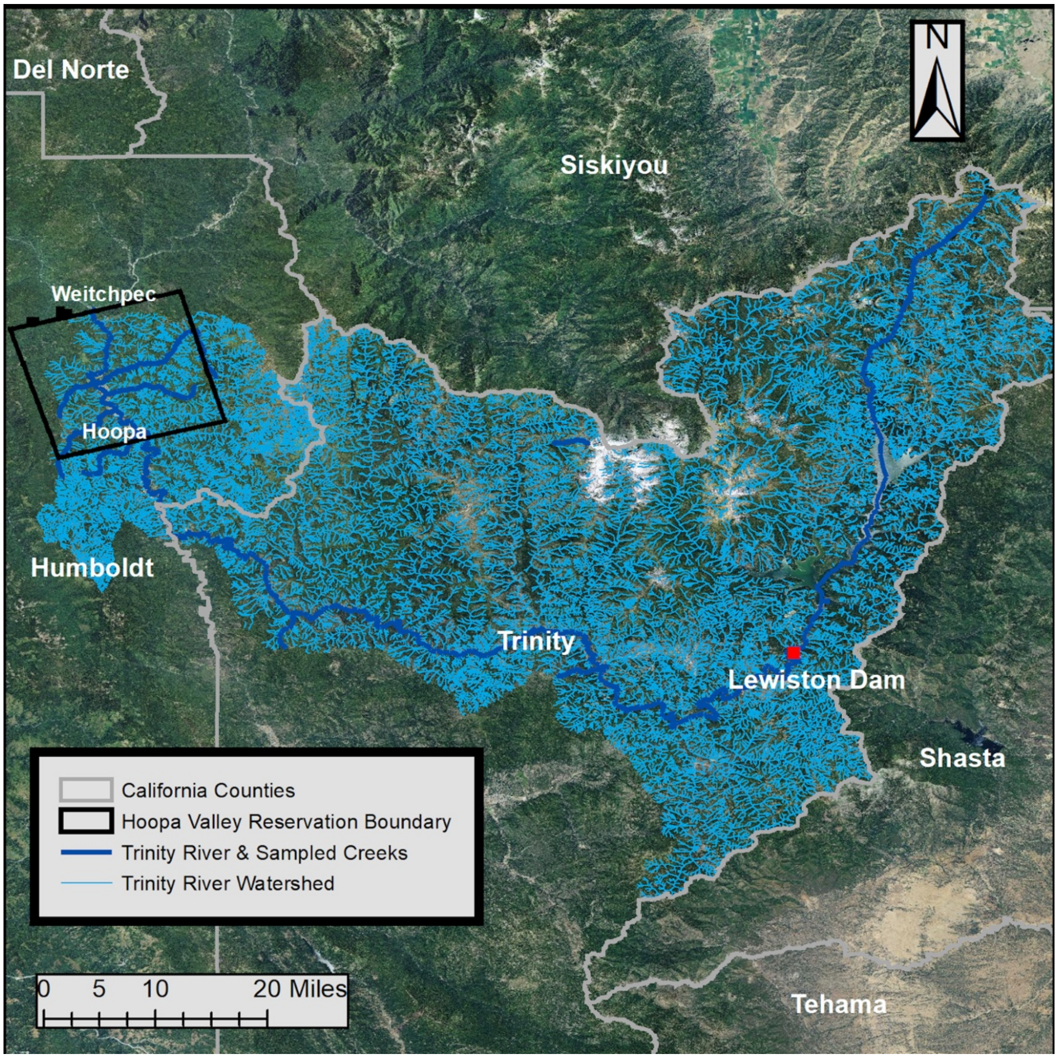

Figure 1. Hoopa Valley Indian Reservation within the Trinity River watershed in Humboldt and Trinity Counties.

The Trinity River, like many rivers in the Pacific Northwest, has a long history of degradation (K. Osborne, pers. comm., 2019). Impacts from mining, timber harvest, water diversion, and other anthropogenic impacts have simplified the river and tributaries which reduce available salmonid habitat (K. Osborne, pers. comm., 2019). Human impacts--including poor logging practices, large scale mining operations, and massive water diversions--combined with the flood event of 1964 to trigger a catastrophic mass wasting event throughout the Trinity River and its tributaries (Trinity River Restoration Program (TRRP), 2019; California Department of Fish and Wildlife (CDFW), 2019). Within the Hoopa Tribal boundaries, mass sedimentation from the flood inundated the valley, destroying riparian vegetation and damaging infrastructure (CDFW, 2019). After the mass wasting events from the flood, the United States Army Corps of Engineers channelized and leveed several of the tributaries to the Trinity River located on the Reservation (CDFW, 2019). Cars cabled together were placed on some of the leveed channels for bank stabilization in the absence of a riparian buffer. The channelization of streams created straight, high velocity flows that transported and removed smaller gravels, leading to bed armoring. The armoring degraded spawning habitat for adult salmonids and reduced overwintering habitat for juvenile salmonids (CDFW, 2019).

Having sufficient year-round habitat available is important for survival of fish during juvenile rearing in streams (Quinn, 2005). During the summer months, salmonids within the Klamath and Trinity River basins often seek refuge in the tributaries (Chiaramonte et al., 2016). As temperatures increase, juvenile salmon move into the smaller creeks, especially during drought years (CDFW, 2019). Coho salmon typically spend one to two years rearing in freshwater before migrating to the ocean environment, with more two-year olds in the northern populations (Ohlberger et al., 2019). Despite the degradation to the Hoopa Valley basin, the tributaries of the Trinity River still have sufficient flows and temperatures to support summer rearing for salmonids, particularly Coho (J. Alvarez, pers. comm., 2019).

To maximize future restoration efforts for Coho and to assess two recent restoration sites, our study posed the following three research questions: 1) When and how are Coho salmon using Hoopa Valley streams? 2) Where are Coho salmon distributed within Hoopa Valley streams in relation to restoration sites? and 3) Do barriers to anadromy effectively obstruct Coho salmon?

To answer these questions, we conducted snorkel surveys of five Trinity River tributaries located on the Hoopa Valley Reservation. The primary goal of our study is to inform restorationists of areas with critical salmonid habitat which may be candidates for restoration.

METHODS

Study Area - *Hoopa Valley Reservation in Humboldt County, California*

Our study sites were located on the following five tributaries of the Trinity River within Reservation boundaries: Campbell, Hostler, Mill, Soctish, and Supply Creek (Figure 2). In 2014, Mill and Supply Creeks received extensive restoration including removal of levees, restoration of natural side channels and meanders, reconnection to flood plains, placement of large woody debris (LWD), and planting of riparian vegetation (CDFW, 2019; J. Alvarez, pers. comm., 2019). Mill and Supply Creeks were targeted for restoration because they are two of the larger tributaries on the Reservation and have habitat known to serve as thermal refugia for Coho salmon when the Trinity River exceeds optimal thermal rearing temperatures (J. Alvarez, pers. comm., 2019). Soctish, Hostler, and Campbell Creeks have not yet received restoration and remain in the armored, channelized down-cut state which Mill and Supply Creeks once experienced.

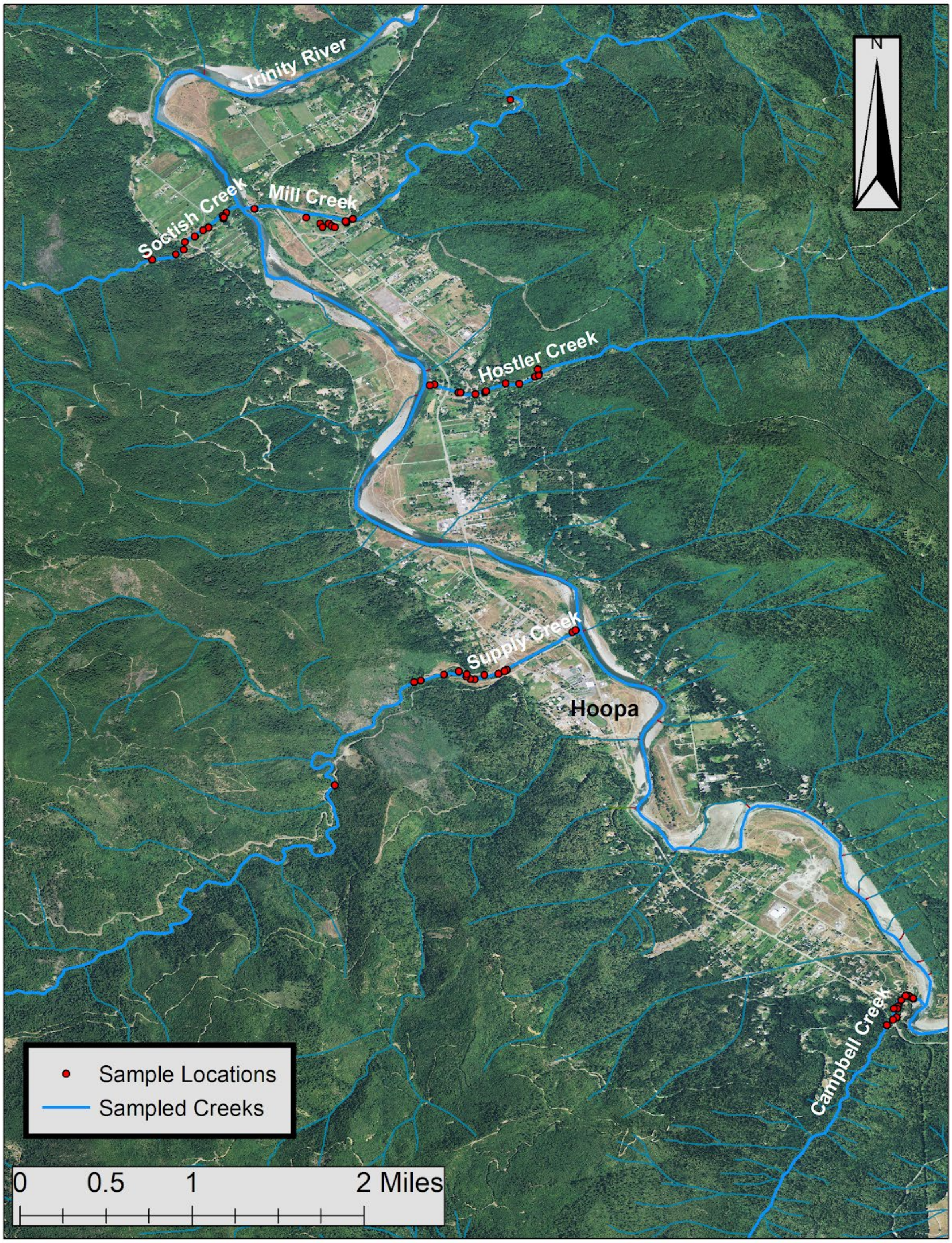

Figure 2. Survey locations on five tributaries off the main stem Trinity River in Humboldt County, California. Study sites occurring on restored streams include Mill and Supply Creeks, and unrestored streams include Soctish, Hostler, and Campbell Creeks.

Field Methods

Snorkel surveys were conducted each month to assess Coho abundance, life history stage, and habitat type utilization within the given streams. Snorkel surveys were the primary method to assess salmonid presence throughout our study sites. A total of 46 snorkel locations were selected within the Hoopa Valley Tribal Reservation: eight sites in Mill Creek, eleven sites in Supply Creek, eight sites in Campbell Creek, nine sites in Soctish Creek, and ten sites in Hostler Creek (Figure 2). Originally, a total of 50 sampling units were identified with ten sampling sites per tributary. However, some sampling units had to be removed from the survey because water levels lowered, creating flows that were too low to conduct surveys. Snorkel surveys were conducted in a joint effort with the Hoopa Tribal Fisheries Department. Snorkel survey units were identified by the Hoopa Tribal Fisheries biologist and Humboldt State University (HSU) student researchers. Sampling units within each tributary were selected to best represent the entirety of the survey reaches. Each individual sampling unit was chosen based on conditions for sampling, as many of the Hoopa Valley tributaries are shallow and make snorkel surveys challenging. Once a sampling site was identified, it was cataloged in a Trimble® Nomad® 900 series handheld computer for future replicate sampling. Traditional snorkel surveying methods were used to count occurrences of four fish species: Coho salmon, Chinook salmon, steelhead trout, and brown trout (Adams, et.al., 2011). All salmonid species and counts were recorded by the Hoopa Tribal Fisheries department and HSU student researchers, but only presence and absence data for Coho salmon was used in this study. Due to the small amount of equipment required for snorkel surveys, the method can be used in remote locations where it may be difficult to use other methods such as traps, nets, and electrofishing (Adams, et.al., 2011). The fish are not handled and disturbance is minimal, so snorkeling is especially useful for sampling rare or protected stocks (O'Neal, 2007). Snorkelers start at the downstream end of a pool swimming slowly upstream. Surveyors collected species counts of salmonid individual's age class: (0+) for young-of-the-year and (1+) for all fish older than one year. Steelhead were the only fish observed as (1+). Additionally, GPS locations, date, and surveyors' names were recorded. Snorkel survey data were recorded using a Trimble® Nomad® 900 series handheld computer, when available, or in Rite in the Rain® notebooks. Snorkel surveys were conducted starting at the mouth of each sample reach, and pools were sampled, in sequential order, in an upstream direction. Snorkel surveys were performed in August, September, and October 2019. August and September surveys were conducted as a joint effort by the Hoopa Valley Tribal Fisheries Department and the HSU student researchers. October 2019 surveys were conducted exclusively by the Hoopa Tribal Fisheries Department. Upon completion of the snorkeling surveys, the Hoopa Tribal Fisheries Department conducted a habitat survey of the five study streams. Habitat data were collected from each individual sampling unit, including residual pool depth, pool length, amount of LWD present, pool type, species abundance counts, area of cover available, and dominant substrate type.

From the data collected, we developed an occupancy model to account for imperfect detection of organisms and determined the probability of the true presence or absence of a species at a site. All data were centralized and processed by the Hoopa Tribal Fisheries Department. The Coho salmon count data were then converted to binary detection/non-detection data by HSU student researchers. The habitat data were left as counts to be used as site covariates. In statistics, a covariate is a variable that is possibly predictive of the outcome under study (MacKenzie et al., 2005). An occupancy model was run to include site covariates such as: residual pool depth, restored or unrestored, pool length, species abundance counts, and number of pieces of LWD. Other covariates were left out of the model because they were too closely correlated to other data, for example the percent instream cover was closely correlated with number of pieces of LWD. The data were then uploaded into United States Geological Survey's (USGS) Program PRESENCE version 12.35 to run occupancy models to determine the best fit of the model. Analysis of Program PRESENCE occupancy data was conducted in Microsoft Excel. Site covariates used in the model are restored or unrestored, residual pool depth, and amount of LWD in pool. Residual pool depth is defined as the pool depth minus the peak of the riffle crest, this accounts for the pool depth at low flows (Lisle, 1987).

RESULTS

Coho, Chinook, and steelhead were detected via snorkeling survey in all of the survey streams during at least one sampling occasion during the study and at least once on each of the sampling days (Table 1). The data were fitted into a Program PRESENCE simple multi-season model. The Akaike's Information Criterion (AIC) that best explained the data for the presence/absence-site occupancy was AIC=275.62. The second-best model had only a slightly higher AIC of 277.62. Although there is not a great deal of difference in the AICs, the lower AIC model was chosen because the extra covariant parameter in the larger model was shown to be to have correlation issues. Available cover, LWD, and steelhead trout counts were excluded as covariates, because they showed no effect or were closely correlated to other more important parameters. The only detection covariant used was dive day, likely due to variation in sampling proficiency of the crew for each dive day. If there was a non-detection for Coho in a sample site using restoration as a covariate for presence, there is a high probability that the Coho is in fact not present if not detected by samplers. The probability of a Coho being present if undetected decreased in likelihood from 52% with no restoration to below 23% in restored sites (Figure 3). The residual pool depth covariate showed that the deeper the pool, it was likely that if a Coho was not detected it was in fact not present in the sampled unit (Figure 4). the probability of occupancy decreased from 63% in shallow pools, to 38% in the deepest pool. Snorkel sampling detection probability decreased with each subsequent sampling day as the sampling season progressed.

Table 1. Observed Coho salmon during each sampling occasion.

	Supply	Mill	Soctish	Campbell	Hostler
August	1	0	2	4	5
September 1	10	0	7	4	0
September 2	2	24	8	2	5
October	3	8	6	0	4

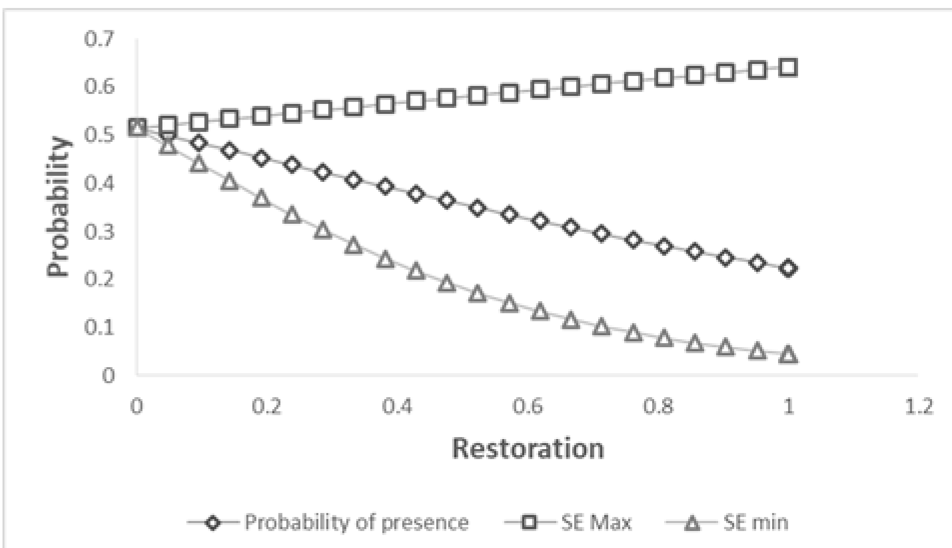

Figure 3. Graph showing the probability that if a Coho is not detected what is the probability that the Coho is in fact absent from the site using Restoration as a covariate. This figure represents the comparison both restored creeks and all unrestored creeks from surveys in 2019.

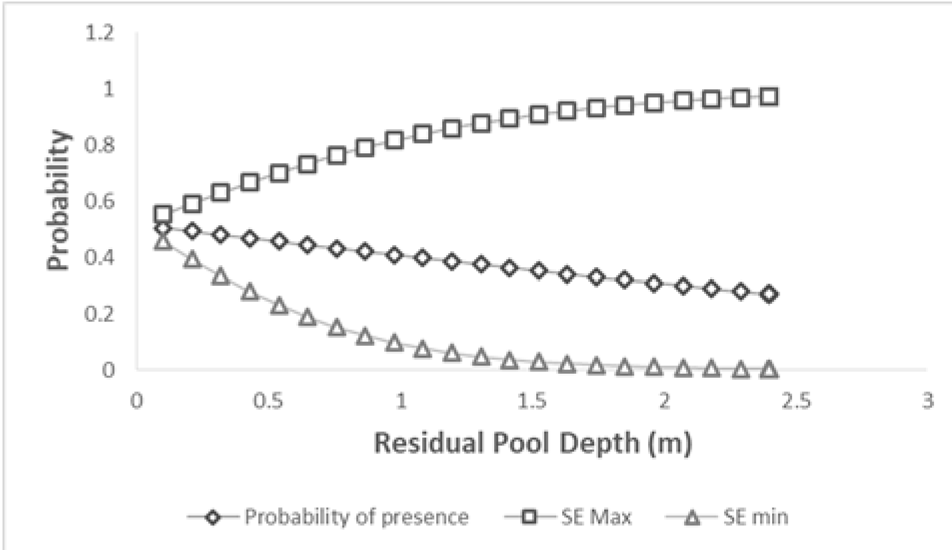

Figure 4. Graph showing the probability that if a Coho is not detected what is the probability that the Coho is in fact absent from the site using residual pool depth as a covariate.

DISCUSSION

Coho salmon were detected in all five sampled streams; however the abundance and timing of detection varied among sites (Table 2). Soctish and Supply Creeks were the only two streams to have positive detections for Coho on each sampling occasion in August, September, and October. As the sampling season progressed, detections and abundance increased in all streams possibly due to Coho exiting the main stem of the Trinity River as seasonal temperatures increased. Sampling techniques also improved after the first sampling occasion in August as inefficiencies were addressed. Flashlights were acquired to aid in snorkeling detection in streams that had heavy riparian cover or large areas of cut banks, which aided surveyors to better detect fish.

Table 2. Fish observation totals from August, September and October 2019 surveys.

	Supply	Mill	Soctish	Campbell	Hostler
Coho	16	32	23	8	14
Chinook	5	54	0	1	0
Age 0 Steelhead	779	1510	614	246	298
Age 1 Steelhead	73	289	76	6	34

Surveyor detection probability showed a declining trend, suggesting that detection probability decreased as the season sampling season progressed. Although detection efficiency decreased with each sequential sampling occasion, counts of Coho increased in all of the five sample streams as the sampling season progressed. The counterintuitive data can be explained by understanding that earlier sampling occasions were performed by samplers with similar snorkel sampling experience, trained snorkelers but with similar novice experience. Later in the season, a diver with expert experience was paired with an inexperienced diver. This could explain why the survey team had wider probability of one diver detecting Coho, while the other did not. Since detection levels were higher and counts of Coho were higher, it was more likely the expert surveyors would detect species of interest while an inexperienced surveyor may have detected the species but not have developed the confidence to properly identify the species by that time.

Although the data suggests restoration, and by association, LWD and instream cover, were linked with a lack of Coho, one must understand the context of the specific sampling sites. LWD and instream cover are correlated with restoration because almost all complexity within the streams are located in restoration reaches. Mill Creek had recent restoration actions and contains most of the LWD located within sampled streams. There were 450 trees with root masses placed within the Mill Creek restoration site, many of which were used as bank armoring on a swift stream bend in place of rip rap (CDFW, 2019; J. Alvarez, pers. comm., 2019). Only one piece of LWD was located outside of a restoration site. The only LWD available in any of the sites was restoration LWD. The Mill Creek restoration site, being such a new restoration action, is void of established riparian vegetation. There are several planted deciduous and coniferous riparian species within the restoration site, but the largest riparian cover is the six-foot-tall willow trees (*Salix sp.*) and alders (*Alnus sp.*) that have naturally recruited over the past few years (J. Alvarez, pers. comm., 2019). These restoration sites are new and continue to develop.

The high amount of complexity added to the stream by restoration action made detection difficult. Despite this observation, our model suggests that even with the added obstructions we can say with high certainty that if a Coho was not detected, it was in fact absent from the site. This is counterintuitive given that in Mill Creek alone, 450 trees with root wads and boulder structures were added to the stream. This helped create undercuts and structural obstructions, giving the juvenile fish ample spaces to avoid detection. In comparison, most of the unrestored streams are channelized, down cut, with significant bed armoring, lacking LWD and cover of any kind. This lack of cover made detection of the juvenile Coho far easier as the fish were in a clear pool of water with no place to hide. A possible explanation for this phenomenon could be a lack of data. There was not a large number of detections for Coho throughout the three-month study leading to a small sample size.

Although Coho salmon were not detected in high numbers in the restoration sites, Chinook salmon were detected in high numbers in the Mill Creek restoration site. In fact, the majority of the Chinook salmon encountered in this study were found within the Mill Creek restoration site (Table 2). This study was not intended to focus on Chinook. As such, these data were given to our Hoopa Tribal Fisheries partners who could use these data to assess the success of their newly implemented restoration site. There were very few other Chinook salmon observed in the study and only the Chinook observed in the Mill Creek restoration site were observed in large groups. The larger numbers that were present in groups likely made Chinook detection easier than that of Coho.

Although our survey does not show that current restoration sites are being utilized by Coho salmon in large numbers, our data has value in informing restoration practitioners. First, juvenile Coho are using restoration sites for thermal refuge, although site complexity affected detection probability. Second, the three unrestored streams are utilized by juvenile Coho in high numbers. Showing that unrestored streams are utilized by Coho and that there is essentially a void in stream complexity will aid the Hoopa Tribal Fisheries department in targeting restoration efforts in the unrestored streams. Increasing stream complexity in unrestored streams will likely also decrease detection probability. Although, it will ultimately benefit juvenile Coho by creating cover to better avoid predation and competition, refuge from high velocity flows, and better habitat partitioning due to increases in habitat complexity.

In conclusion, the results of this study suggest that Coho salmon are utilizing restoration sites on Mill and Supply Creeks, but detection probability is lower in restoration sites because of higher levels of habitat complexity. Unrestored streams, while having higher detection probability, have a need for restoration based on the lack of habitat complexity, which aids in ease of detection. The Hoopa Valley streams are shown to serve as thermal refuge sites for juvenile Coho salmon, and further restoration of streams would benefit threatened Coho salmon as well as other species of salmonids.

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