Big Chico Creek
2013 Fish Population Survey

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Introduction

Steelhead (*Oncorhynchus mykiss*) were once abundant throughout the Central Valley (CV) rivers, until numerous anthropogenic factors reduced and degraded their spawning and rearing habitat (McEwan 2001). Lindley et al. (2006) proposed 81 historical independent populations of steelhead in the CV, and nearly all existing populations are considered data deficient (Lindley et al. 2007, National Marine Fisheries Service 2009). Due to the limited availability of geographically specific *O. mykiss* data, information from one population of the CV steelhead Evolutionarily Significant Unit (ESU) is often applied to another despite the heterogeneity in environmental conditions across the distribution of the ESU.

Central Valley *O. mykiss* show considerable plasticity in life history traits, which presents a challenge for fisheries management (Satterthwaite et al. 2010). Individuals may migrate out to sea (i.e., steelhead) at various ages or remain in freshwater as residents (i.e., rainbow trout). Additionally, some individuals may migrate out to the Sacramento-San Joaquin estuary and San Francisco Bay, and return without spending any time in the open ocean (Teo et al. 2011, Null et al. 2012). In some, and maybe all, rivers, both steelhead and resident adult females can produce steelhead and resident offspring (Zimmerman and Reeves 2000, Heath et al. 2008, Zimmerman et al. 2009, Courter et al. 2009, Christie et al. 2011), complicating the assessment of steelhead population viability in the region. Management of steelhead depends on the prevalence of the migratory polymorphism, and within the CV ESU it may not be possible to manage one morph without reference to the other (Williams et al. 2007). Without information regarding the abundance of *O. mykiss* or the prevalence of various life history morphs, it is difficult to examine how changes in the environment may affect the population abundance as a whole. Consistent and robust population monitoring is necessary to document trends and natural variation in *O. mykiss* abundance, and to understand whether certain actions may negatively or positively affect abundances (Eilers et al. 2010).

Big Chico Creek is a Central Valley stream that supports populations of both steelhead and resident rainbow trout (Figure 1). The creek originates on the western slope of Colby Mountain, at an elevation of 5,400 feet, and flows 45 miles to its confluence with the Sacramento River. Higgin's Hole, a natural barrier, is considered the upstream boundary for migratory fish species, leaving approximately 24 miles of the stream accessible to anadromous fish (USFWS AFRP). In the fall of 1986, the California Department of Fish and Wildlife (then California Department of Fish and Game), treated the creek with rotenone (a piscicide). The treatment, affecting the reach between Higgin's Hole and Iron Canyon, was conducted in response to perceived competition from non-game fish on salmonids. Between 1987 and 1991, over 1.5 million Chinook salmon fry and several hundred thousand steelhead fry, from Feather River stock, were planted in the creek just below Higgin's Hole (BCCWA 1997).

Following the rotenone treatment, California State University, Chico professor Paul Maslin and his limnology class conducted annual surveys from 1986-1998. Using depletion electrofishing, they surveyed fish populations at three sites on Big Chico Creek. The overall effectiveness of the rotenone treatment, with respect to restoring anadromous fish populations, remains unclear

(Maslin 1997). While populations of rainbow trout generally increased slightly over the study period it was unclear if this was a result of reduced competition/predation or a result of massive stocking efforts and stochastic weather events (i.e., winter flooding). The population of exotic brown trout (*Salmo trutta*) increased after the treatment, and their range appears to have expanded to downstream reaches where the species had not been detected previously. Re-colonization by non-game fish was far less successful. Native cyprinids were extremely slow to re-colonize the treated middle zone of the creek, and only California roach (*Lavinia symmetricus*) were observed at high abundances. No hardhead (*Mylopharodon conocephalus*) and only two Sacramento pikeminnow (*Ptychocheilus grandis*) were observed in the study area after the treatment. Limited numbers of Sacramento suckers (*Catostomus occidentalis*) were documented after the treatment with all less than 300mm in length. The population of riffle sculpin (*Cottus gulosus*) rebounded close to pre-treatment levels, with considerable recruitment being observed after the 1997 flood events (Maslin 1997).

Despite the increasingly recognized need to incorporate resident rainbow trout populations in status assessment and management of the steelhead CV ESU, no efforts have been directed at a quantitative assessment of Big Chico Creek fish populations in over a decade. In August 2013, we surveyed a reach of Big Chico Creek, located within the Big Chico Creek Ecological Reserve (BCCER; Figure 1), to obtain an estimate of total trout abundance.

There are many methods for estimating the total abundance of fish in freshwater systems, the majority of which depend on handling the fish during enumeration (e.g., electrofishing, seining etc.). Direct observation dive counts (i.e., snorkel surveys) are a cost effective, non-invasive means of estimating abundance based on visual counts, which do not require fish handling (Allen and Gast 2007). Therefore, this method is preferred for listed species and species of special concern. In some situations, when water visibility is excellent and conditions are good, snorkeling can provide counts similar to depletion electrofishing (Mullner et al. 1998). Visual estimates, however, are typically negatively biased, since certain factors can affect fish detectability (e.g., visibility, temperature, time of day, species-specific behaviors and fish size) (Northcote and Wilkie 1963 as cited by Hagen and Baxter 2005, Mullner et al. 1998, Bradford and Higgins 2001, Hagen and Baxter 2005, O'Neal 2007, Hagen et al. 2010). Therefore, without estimates of observer bias (generally requiring depletion estimates of abundance for a subsample of the reaches under study), single pass snorkel surveys cannot provide an estimate of absolute abundance; rather, they provide an unbiased index of abundance with associated confidence intervals.

A viable alternative to obtaining accurate population size estimates by traditional methods (such as depletion electrofishing or mark-resighting experiments) is the Method of Bounded Counts (MBC). This approach relies on repeat counts of fish from the same unit (generally four passes), and produces nearly unbiased estimates of abundance if fish abundance in respective survey units is relatively low (Mohr and Hankin 2005). As such, this method provides a non-invasive (no fish handling required) alternative to traditional methods that is highly applicable to stream surveys involving species of special concern. We used the MBC on Big Chico Creek to obtain estimates, rather than indices, of trout abundance, and to provide a renewed assessment of the fish community in this reach.

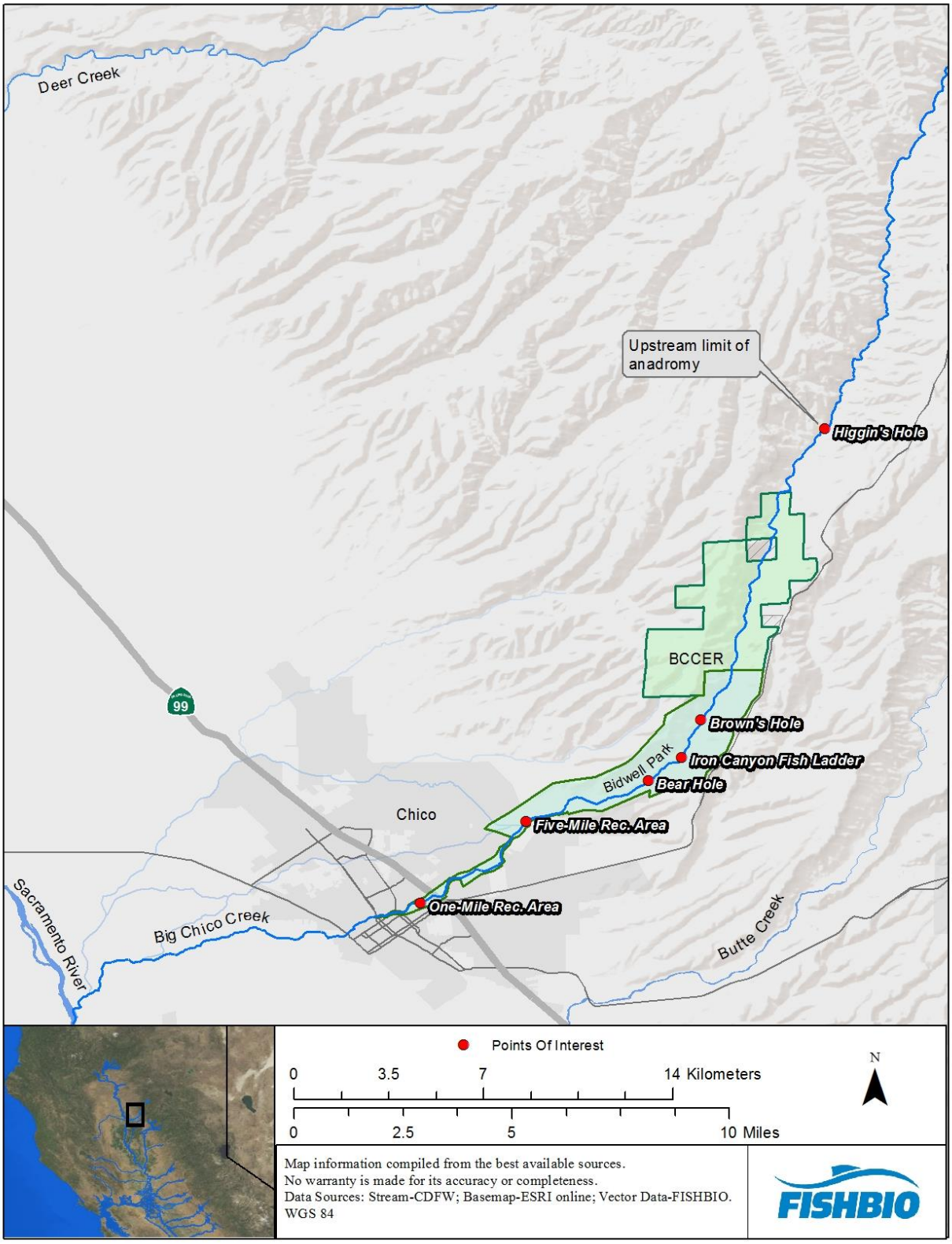

Figure 1. Map of Big Chico Creek watershed

Methods

Study Site

Big Chico Creek is one of several small eastside tributaries to the Sacramento River, along with Butte Creek, Deer Creek, Mill Creek and Antelope Creek, that have comparable topography and annual discharge patterns. These creeks flow into the Sacramento River within approximately 40 miles of one another, are mostly undammed and are all considered high priority watersheds for conservation and restoration of anadromous fish populations.

Big Chico Creek can be roughly divided into three different zones, based both on geological barriers and the species composition, especially fish, inhabiting each zone. The lowest geological barrier is located in Upper Bidwell Park, between Brown's Hole and Bear Hole, in an area known as Iron Canyon (Figure 1). In this narrow canyon, as the creek flows over a geologic formation known as the Lovejoy basalt, years of erosion have resulted in an assemblage of large basalt boulders in the middle of the creek. The arrangement of these boulders has formed impassable barriers to anadromous fish during normal flows, but during high flows, upstream migration past Iron Canyon is possible (DWR 2002). The timing of high flows, along with the timing of fish migrations, has a significant effect on the accessibility of the upper stretch of creek by various fish species. Steelhead, migrating between November and February, can typically navigate this barrier. Other species, such as spring- and fall-run Chinook salmon, with different migration times, often have difficulty passing this section of the creek (DWR 2002). It is unclear whether resident species such as Sacramento pikeminnow, hardhead, Sacramento suckers, and smallmouth bass (*Micropterus dolomieu*) can pass this barrier. However, their inability to re-colonize the foothill zone following the rotenone treatment, suggests that they have difficulty migrating upstream through Iron Canyon. Although a fish ladder was built in this area in the 1950's, years of deterioration and absence of maintenance have rendered it ineffective.

The next geological barrier is Higgin's Hole, where a large waterfall forms the upstream barrier to anadromous fish migration on Big Chico Creek. These two barriers establish the separation of the creek into three zones: the upper zone (mountain zone) above Higgin's Hole, the middle zone (foothill zone) between Higgin's Hole and Iron Canyon, and the lower zone (valley zone) below Iron Canyon to the confluence with the Sacramento River (Figure 1).

The foothill zone (Figure 1) is the most important reach to anadromous fish populations, as the lower zone does not provide much suitable spawning habitat, has larger populations of predatory fish and experiences seasonally high water temperatures in excess of the physiological tolerance of salmonids (BCCWA 1997). Historically, anadromous fish dominated the foothill zone, and populations of Chinook salmon, steelhead, and Pacific lamprey (*Lampetra tridentata*) were prominent in this reach. Populations of native cyprinids, including hardhead, Sacramento pikeminnow, and California roach, as well as brown trout, Sacramento suckers, and riffle sculpin were also found in the foothill zone of Big Chico Creek (Maslin 1997, BCCWA 1997).

The Big Chico Creek Ecological Reserve, a 3,950 acre parcel of land which encompasses an estimated four and a half miles of Big Chico Creek, is located about 0.5 miles downstream from Higgin's Hole. The BCCER was chosen for this study as it provides public access along a relatively large section of the creek that is located only a short distance below the barrier to anadromy. With the possible exception of the 0.5 mile long reach between the upstream reserve boundary and Higgin's Hole, the portion of Big Chico Creek located within the BCCER likely provides the highest quality anadromous habitat in the watershed.

Habitat Mapping and Unit Selection

In order to obtain an accurate estimate of fish abundance, the entire reach of Big Chico Creek within the BCCER, was surveyed on foot and categorized into habitat units based on a four-category classification (i.e. riffle, run, pool, and cascade). GPS waypoints were taken at the boundaries of each habitat unit using a hand held Garmin® GPS unit (Garmin International Inc., Olathe, KS), in order to accurately locate each habitat unit during subsequent surveys. In addition, the length of each unit was measured with a Bushnell® rangefinder (Bushnell Outdoor Products, Overland Park, KS) and recorded. Discharge, in cubic feet per second (cfs), was estimated at two locations within the BCCER. During habitat mapping, units that appeared to pose potential hazards to snorkelers or were otherwise unsuitable for the proposed survey type were identified. Stream sections classified as "cascades" are often hazardous or do not permit sufficient visual coverage due to turbulence and were excluded from this survey.

Within each stratum (run, riffle, pool), units were sampled systematically by generating a random number between 1 and 5, and subsequently surveying every k^{th} unit in a downstream direction. Depending on habitat type, approximately one fifth of all the units were surveyed (see Table 1). A sub-sample of the surveyed units was randomly selected for calibration of dive counts, using the MBC technique described in more detail below.

Dive Counts

Snorkel surveys were conducted on August 7-9, 2013. A standardized protocol was followed to ensure comparability of survey results over subsequent years and to minimize variation due to sampling error. The number of divers needed for a snorkel survey depended on the width of the stream, but was chosen to ensure complete visual coverage of the stream during upstream snorkeling. If the stream section to be surveyed required more than two divers for complete visual coverage of the stream width, parallel dive lanes were established prior to snorkeling. Dive lanes were assigned randomly to divers at each survey unit to minimize the effects of diver familiarity with the physical habitat and fish population on dive counts. Care was taken to minimize disturbance of fish prior to sampling each unit.

Divers entered the stream at the downstream border of the survey reach and counted fish within their respective dive lanes as they proceeded upstream, in unison with the other divers. Divers recorded fish counts on a wrist mounted dive slate, and assigned a size category to each

observation (less than 150mm, 150-300mm, and greater than 300mm). To facilitate the correct estimation of fish size and account for underwater size distortion, divers were equipped two reference dowels (150mm and 300mm in length). When approaching the upstream boundary of the survey unit, divers carefully monitored fish holding close to the unit boundary and included fish that crossed the unit boundary in an upstream direction. Any fish that was observed moving between lanes was noted immediately after the dive to avoid multiple counts of the same fish.

In order to allow for the estimation of abundance, rather than indices of abundance, it was necessary to calibrate single pass dive counts. Rarely is it possible for divers to observe every fish within a survey unit, therefore, in the vast majority of cases, single pass snorkel survey counts are negatively biased. The Method of Bounded Counts (MBC) is a non-invasive method for calibrating single pass dive counts by using counts obtained during three additional passes through the same unit. To minimize potential observer bias during all snorkel passes, the units selected for additional passes were not revealed to the divers until the first dive pass was completed. The sample unit was allowed to rest for a minimum of five minutes between dives.

Obtaining accurate counts of *O. mykiss* and *S. trutta* was the priority of this survey. Other observed species (and their lengths) were recorded, so long as it did not compromise counts of the focal species.

Fish Abundance

To estimate total abundance of focal fish species, a two-phase calibration design estimator was used in each stratum surveyed (runs, riffles and pools). Error in the estimation occurs in both phases of the survey design. Error that occurs in the first phase is called sampling variance, or error that arises from selecting any sample from a sampling universe. Sampling variance can be minimized by selecting an adequate number of samples from all that are available in a given strata. In the second phase (in units selected for bounded counts), there is error associated with the measurement of any particular unit abundance (measurement error or precision) due to variation of dive counts within units dove multiple times. Data from each of the four pass counts was ordered from highest to lowest, and unit abundance was estimated as:

$$\tilde{y}_{Bk} = d_m + (d_m - d_{m-1})$$

where $\tilde{y}_{Bk}$ = the bounded count estimate of "true" abundance in unit k, d_m = the largest of the four counts for the unit, and $d_{m\text{-}1}$ = the second largest of the four counts the unit.

For example, if a unit was snorkeled four times with pass counts of 6, 7, 9, and 6 fish, the ordered counts would be 9, 7, 6, and 6. The difference between the highest count (9) and the next highest count (7) is 2, and would be added to the highest pass count of 9, for an estimate of 11 fish in the unit.

The estimate of error, or mean square error (MSE), around the unit abundance estimate was calculated as

$$\widehat{MSE}_{\tilde{y}_{Bk}} = (d_m - d_{m-1})^2$$

In the preceding example, the MSE would equal the squared difference between the highest count (9) and the next highest count (7), which would equal 4. The 95% confidence intervals would be twice the square root of MSE, again, which would equal 4, for a final unit abundance estimate of 11 ± 4 (7 – 15).

For each stratum in which surveys were conducted, the total stratum abundance ($\hat{Y}_D$) is estimated as

$$\hat{Y}_D = \mathrm{N}\bar{\tilde{y}}_{BD}\frac{\bar{x}_1}{\bar{x}_2}$$

where N = the number of habitat units within stratum *D*, and $\bar{\tilde{y}}_{BD}$ is the mean estimated total abundance for all units in stratum D for which bounded counts were performed. The last term in the equation is the mean of the first pass counts in units that were dove only once ($\bar{x}_1$) divided by the mean of the first pass counts in units that were dove four times ($\bar{x}_2$). This is an adjustment factor that accounts for the observation probability during the snorkel surveys (i.e., the difference between a unit abundance derived from a single-pass survey versus a four-pass survey).

Estimates of error around the total stratum abundance were calculated as

$$\hat{V}\left(\hat{Y}_D\right) = N^2(1-f_1)\frac{s^2_{\tilde{y}}}{n_1} + N^2(1-f_2)\left(\frac{\bar{x}_1}{\bar{x}_2}\right)^2\frac{s^2_{\tilde{y}|x}}{n_2}$$

where f_1 and f_2 are the sampling fractions for the first and second phases, respectively; n_1 and n_2 are the numbers of units that are sampled in the first and second phases, respectively. The variation in the unit counts in the first phase, $s^2_{\tilde{y}}$, was calculated as

$$s^2_{\tilde{y}} = \frac{1}{n_2 - 1}\sum_{k=1}^{n_2}(\tilde{y}_{Bk} - \bar{\tilde{y}}_{BD})^2$$

where $\tilde{y}_{Bk}$ is the estimated abundance in the k^{th} second phase sample and $\bar{\tilde{y}}_{BD}$ is the mean abundance over all second phase samples in stratum *D*. The conditional variation (i.e., variation that arises from selecting particular second phase samples), $s^2_{\tilde{y}|x}$, was calculated as

$$s^2_{\tilde{y}|x} = \frac{1}{n_2-1}\sum_{k=1}^{n_2}\left[MSE_{\tilde{y}_{Bk}} + (\tilde{y}_{Bk} - \bar{\tilde{y}}_{BD}\frac{x_{Bk}}{\bar{x}_2})^2\right]$$

where x_{Bk} is the first pass dive count in unit k.

Sampling in a stratified design such as the one employed is considered independent across the different habitat strata (run, riffle, pool; D = 1, 2, 3), so that estimates of total abundance for each of the habitat types, $\hat{Y}_D$, and their corresponding sampling variances, $\hat{V}(\hat{Y}_D)$, can be combined across strata (Thompson 2002):

$$\hat{Y} = \sum_{D=1}^{3} \hat{Y}_D$$

and

$$\hat{V}(\hat{Y}) = \sum_{D=1}^{3} \hat{V}(\hat{Y}_D)$$

Note that the estimates of abundance do not account for cascade habitat units that were not sampled due to safety concerns and poor visibility. This habitat type accounted for 6.7 percent of the total length of the stream within the reserve (Table 1).

Results

Habitat Mapping and Unit Selection

According to our classification, the reach of Big Chico Creek within the reserve consists of 208 habitat units: 51 pools; 55 riffles; 73 runs; and 29 cascades. Snorkel surveys were conducted on 11 pools, 14 runs, and 10 riffles. Additionally, 15 of the 35 surveyed units were selected for bounded counts.

Table 1. Habitat unit composition and percentage surveyed during snorkel surveys conducted on Big Chico Creek on August 7th and 8th, 2013.

Habitat Type	Count of Type	Sum of Length (m)	Percent by Length	Units Surveyed	Length of Units Surveyed (m)	Percent of Type Surveyed
Pool	51	3001	41.7	11	753	25.1
Riffle	55	1484	20.6	10	279	18.8
Run	73	2226	31.0	14	501	22.5
Cascade	29	484	6.7	0	0	0
Total	208	7195	100	35	1533	21.3

Fish Abundance

Overall, five species of fish were observed in the BCCER snorkel survey, including: rainbow trout, brown trout, Sacramento sucker, riffle sculpin, and California roach. With the exception of California roach - which were too numerous to count in nearly every habitat unit that was snorkeled - rainbow trout were the most abundant species observed, followed by Sacramento suckers, brown trout, and sculpin. We observed 203 rainbow trout and 16 brown trout during the first pass of snorkel surveys (Figure 2). We estimated that there were approximately 2,525 rainbow trout in the reach of Big Chico Creek within the reserve, or approximately 561 fish per mile. We estimated a total of 188 brown trout in the reserve (approximately 42 per mile). Estimates were not calculated for the other three species, but a total of 36 suckers and three sculpin were observed during the first pass of snorkel surveys. One adult steelhead was observed during the survey.

Size distinctions were noted for rainbow and brown trout. We estimated that there were 1,638 juvenile rainbow trout (<150mm), 711 rainbow trout between 150 and 300mm in length, and 176 rainbow trout larger than 300mm in the reserve (Figure 3). The majority of brown trout were juveniles, with an estimated 159 brown trout smaller than 150mm, 16 brown trout between 150 and 300mm, and 13 brown trout greater than 300mm in length (Figure 4).

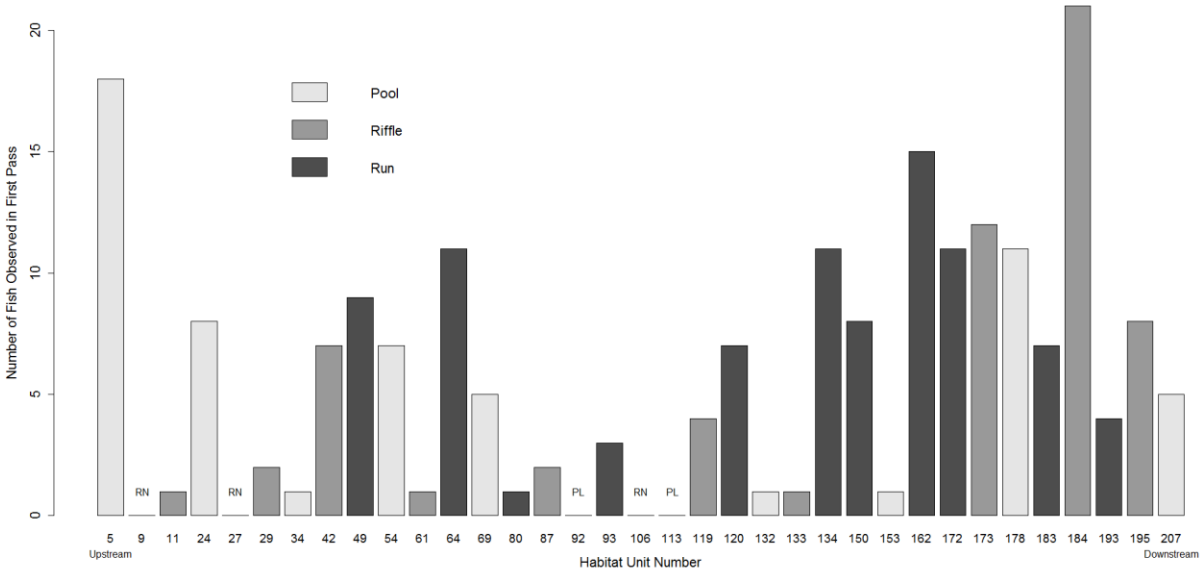

Figure 2. Number of *Oncorhynchus mykiss* (all size classes combined) observed during the first pass of snorkel surveys conducted on August 7th - 9th, 2013, on the Big Chico Creek Ecological Reserve.

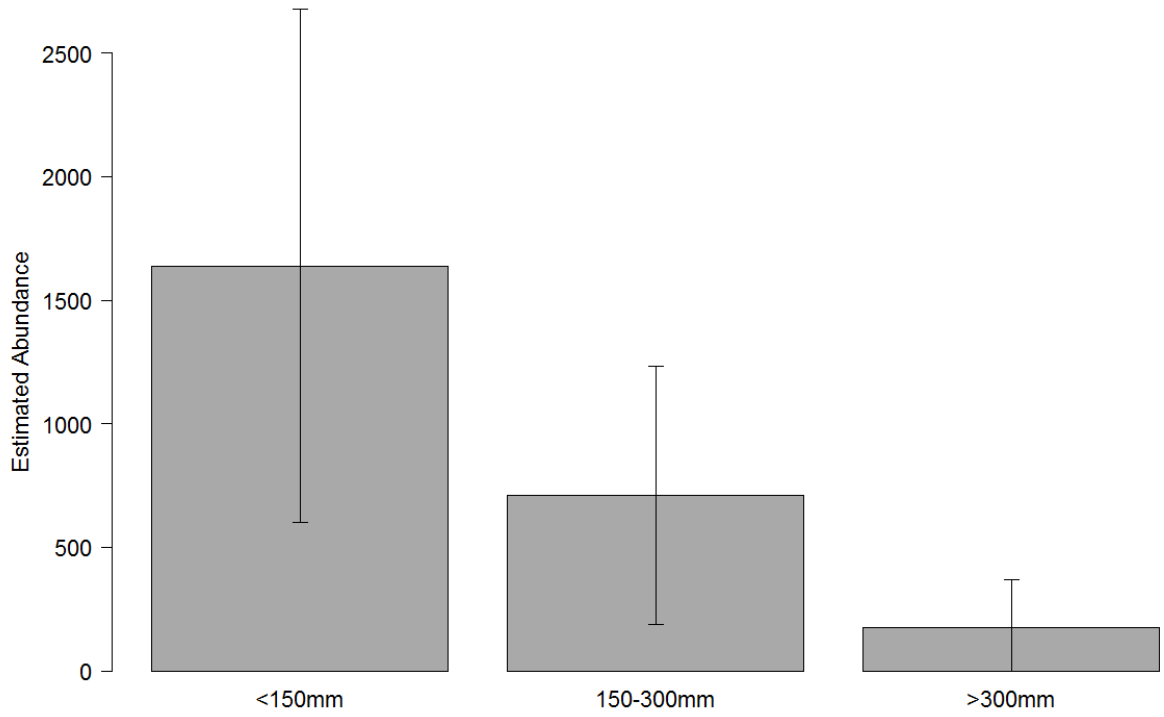

Figure 3. Estimated number of *Oncorhynchus mykiss*, by size category, on the Big Chico Creek Ecological Reserve in August, 2013. Error bars represent one standard error.

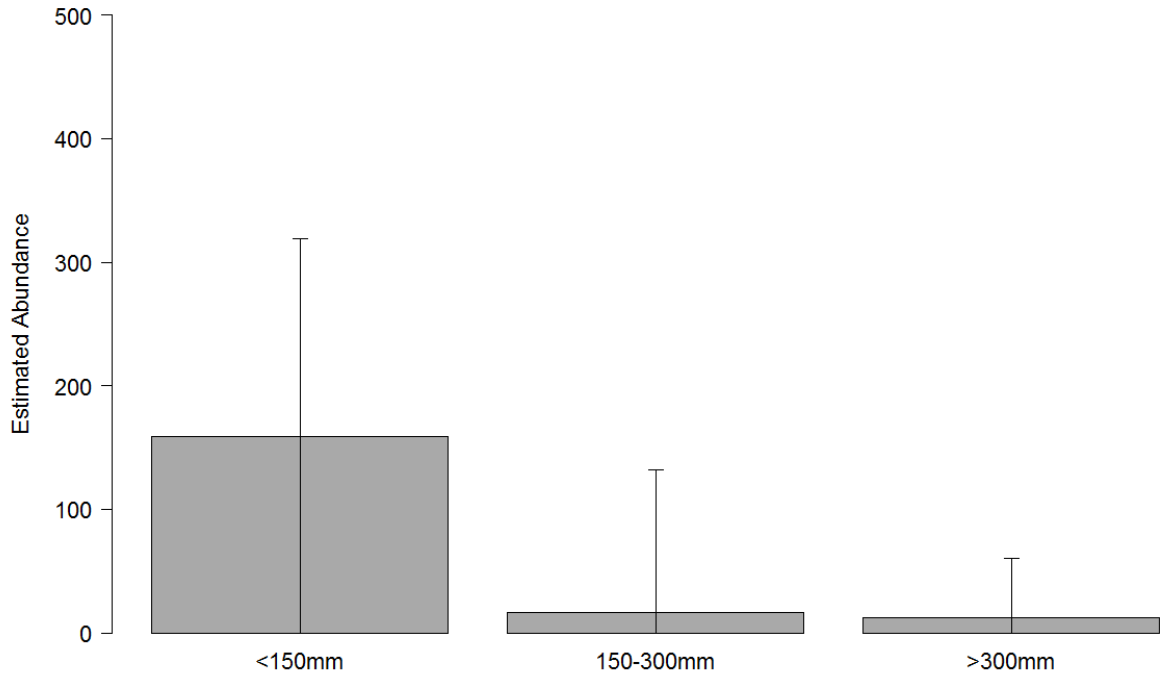

Figure 4. Estimated number of *Salmo trutta*, by size category, on the Big Chico Creek Ecological Reserve in August, 2013. Error bars represent one standard error.

Overall, the majority of fish were observed in runs, followed by riffles, and pools. Habitat use by rainbow and brown trout was slightly different. Rainbow trout were predominantly observed in runs, with 1,487 fish estimated to inhabit runs on the reserve. We also estimated that there were 559 rainbow trout inhabiting pools and 479 rainbow trout inhabiting riffles in the reserve (Figure 5). While rainbow trout were observed in every sampled riffle (Table 2), the comparatively low overall abundance of the species in this habitat type can be explained by the small size and shallow depth typical of riffles found in the reserve. Brown trout, in contrast, were more abundant in riffles than other habitat types, with 110 fish estimated to inhabit riffles on the reserve, all of them individuals measuring less than 150mm. We estimated that there were 65 brown trout inhabiting runs and 13 brown trout inhabiting pools within the reserve boundaries (Figure 5).

In addition to the fish species named in preceding paragraphs, we also observed 19 Western pond turtles (*Actinemys marmorata*) during our survey. They were observed in all three habitat types, but were observed most frequently in riffles.

Table 2. Percentage of habitat units in which each species (all size classes combined) was observed during snorkel surveys conducted on Big Chico Creek during 8/7-8/9/2013 on the BCCER.

Common Name	Scientific Name	Pool	Riffle	Run
Rainbow trout	*Oncorhynchus mykiss*	81.8	100.0	78.6
Brown trout	*Salmo trutta*	27.3	30.0	28.6
Sacramento sucker	*Catostomus occidentalis*	18.2	10.0	35.7
Riffle sculpin	*Cottus gulosus*	9.1	10.0	7.1
California roach	*Lavinia symmetricus*	100.0	100.0	100.0

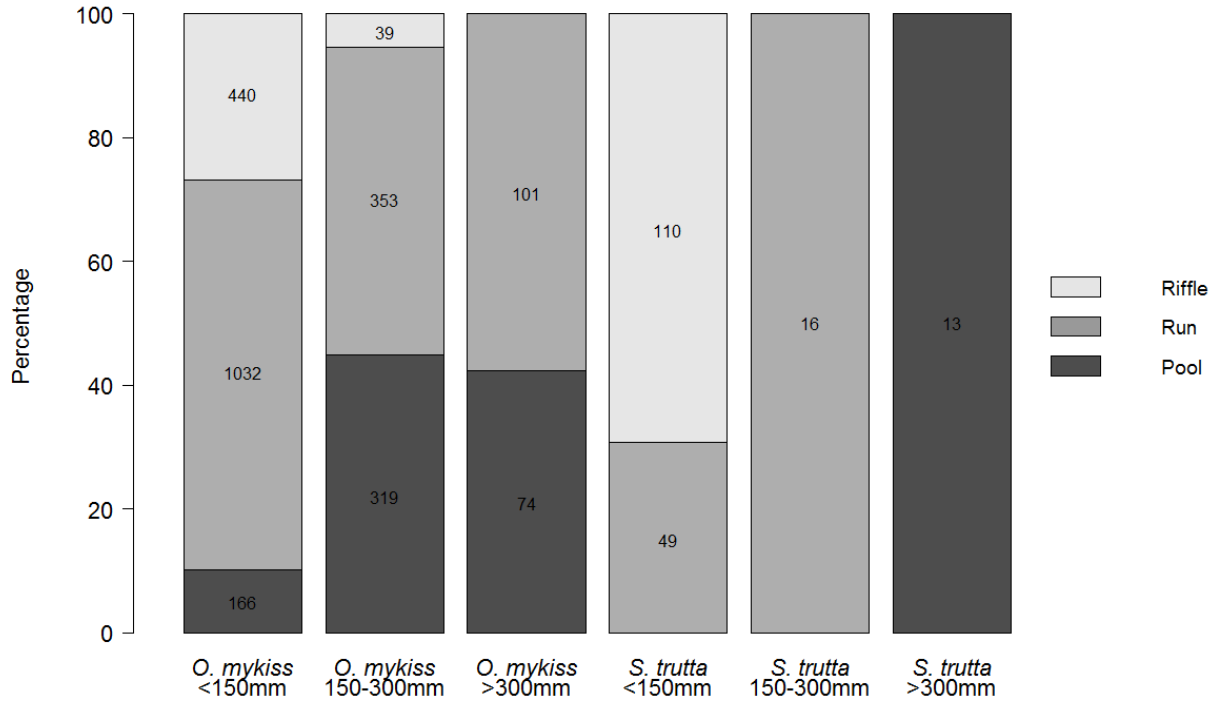

Figure 5. Habitat occupancy of *O. mykiss* and *S. trutta* in Big Chico Creek, by size class, estimated from snorkel surveys conducted on August 7th - 9th, 2013, on the Big Chico Creek Ecological Reserve.

Stream Characteristics

Temperature data was recorded during habitat mapping on July 31, 2013 and ranged from 17-19°C depending on location and time of day. Following the survey, two Temperature gauges were placed in the creek, near the upper and lower boundaries of the reserve. In the week following the survey, high temperatures of 21.5°C and 19.8°C were recorded for the upper and lower gauges, respectively. Discharge was estimated at two locations on the reserve by measuring stream depth and flow along a cross section of the creek. Near the upper boundary of the reserve, the estimated discharge was 26.8 cubic feet per second (cfs), while near the lower reserve boundary, estimated discharge was 12.6 cfs. These measurements, however, were taken in a low-velocity area where flow meters frequently underestimate actual current velocity. As a result, discharge is likely underestimated at this location.

Discussion

Very limited information exists regarding the abundance of rainbow trout in anadromous waters of Northern California. This is especially concerning considering the listed status of steelhead and findings of several recent studies, which demonstrated the ability of resident rainbow trout to produce migratory offspring (e.g., Zimmerman et al. 2009, Courter et al. 2013). Consequently, it seems that a greater emphasis should be placed on monitoring and conservation of the local resident trout populations as a gene bank and potential source population of the steelhead life-history type.

This study, though relatively small in scale and scope, is the only recent study we are aware of that attempts to quantify actual summertime abundance of rainbow trout in eastside tributaries to the Sacramento River. We do not know how many, if any (with the exception of one adult steelhead that was observed during our surveys), of the rainbow trout inhabiting Big Chico Creek within the reserve, may emigrate and assume the migratory behavior that typifies steelhead. Given the limited amounted of available data, the abundance estimates presented in this study provide a much needed and current quantification of "potential steelhead" in the Northern Central Valley. As such, we consider this survey an important reference for comparison to other local tributaries of the Sacramento River.

We attempted to obtain data on trout abundance from multiple agencies involved in monitoring fish populations in Northern California, and found only one study which attempted to enumerate trout in one of the above mentioned eastside tributaries (most monitoring efforts are devoted to spring-run Chinook salmon, not *O. mykiss*). The Heritage and Wild Trout Program (CDFW) monitors spring-run Chinook salmon and steelhead in Antelope Creek (Tehama County). In the summer of 2013, they conducted direct observation surveys for trout and other resident fish along a 12-mile reach of the stream. Using abundance indices, rather than actual abundance estimates, they calculated a density of 362 rainbow trout per mile (CDFW 2013b). Acknowledging the stark differences in study design and estimation techniques, rainbow trout abundance in Big Chico Creek (561 *O. mykiss*/mile) appears on par with, or higher, than other Northern California streams such as Antelope Creek.

In reference to previous accounts of the fish community of Big Chico Creek, several species were conspicuously absent from the surveyed reach. No spring-run Chinook salmon, Pacific lamprey, Sacramento pikeminnow, hardhead, or adult Sacramento sucker were observed. Historically, these species comprised a large percentage of the fish community. Our findings, in corroboration with observations made by Dr. Maslin, are suggestive of long-term detrimental effects of the rotenone treatment on native fish communities. The use of a piscicide on Big Chico Creek, however, cannot be blamed for the absence of anadromous fish, such as spring-run Chinook salmon. In recent years, salmon escapement has been intermittent, ranging from zero to 299 since 2001 (avg. = 49; CDFW 2013a), and is probably most affected by the timing of high flows through Iron Canyon. Also, it should be noted that a lack of observations during snorkel surveys does not constitute absence of a particular species. As only about 20% of the total creek length within the reserve was surveyed, it is possible that some of the species that we did not

observe are present on the BCCER in habitat units not included in our sample. Additionally, as snorkel surveys are designed to detect a particular suite of species, observations of non-target species can often be affected by species-specific behaviors (e.g., burrowing by lamprey ammocoetes). Other factors that affect fish detectability (visibility, temperature, time of day, and fish size) are likely negligible considering the relatively small size and low turbidity of this stream during the summer months.

Despite the above-described limitations, it appears that the relative species composition of Big Chico Creek is markedly different than it was prior to the rotenone treatment of 1986. The population of rainbow trout was prominent throughout the reserve, although it is difficult to ascertain information on population health without estimates from similarly standardized surveys. Based on observations from previous surveys conducted by Dr. Maslin, it appears that the population of exotic brown trout has increased and expanded downstream to Upper Bidwell Park following the removal of non-game fish. The population of native California roach has likely increased following the removal of native predators. Although this study did not collect precise counts of California roach, it was clear that the species was abundant.

The abundance estimates reported in this study will serve as a baseline for evaluating trends and inter-annual comparisons of fish community composition and abundance. Future surveys may also document the presence of spring-run Chinook salmon, Pacific lamprey, Sacramento pikeminnow, hardhead, and large Sacramento suckers, all of which were not observed in this study. Furthermore, an expansion of the study area, both on Big Chico Creek (extending the survey reach upstream to Higgin's Hole) and to other comparable, nearby tributaries of the Sacramento River, is desirable. This expansion would provide comparative abundance estimates and better quantify the recovery potential inherent to resident rainbow trout populations.

Lastly, the relatively high density of *O. mykiss* estimated in this study is a testament to the importance of Big Chico Creek and specifically, the Big Chico Creek Ecological Reserve, to the conservation and recovery of Central Valley steelhead. The presence of an adult steelhead on the reserve confirms the importance of this habitat to the threatened species, and the need for continual monitoring of resident trout populations.

Acknowledgements

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