A Physical Habitat Assessment of Alameda Creek used to Determine the Suitability for Reintroducing Native Fish Species.

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Abstract Adjacent land use to a creek, such as urban development, alters the natural hydrological conditions of many streams often resulting in the degradation of water quality, physical habitat, and biotic integrity of the ecosystem. In particular, native fish populations are heavily dependent upon favorable characteristics of a healthy stream (i.e. channel flow status, riffle/pool variability, sediment deposition, available cover, etc.) This paper summarizes qualitative data on overall stream health collected from Alameda Creek, a 30-mile long urban stream in the East Bay Area, California. The data help determine whether Alameda Creek has suitable physical habitat quality required for the successful reintroduction of native fish species including Steelhead trout, Coho Salmon, and Chinook salmon. Habitat requirements varied amongst various native fish life history stages. Data was collected monthly (February – April) at nine sites along the stream based on type of adjacent land use (Urban, Auto/Rail Overpass, or Natural). Ten parameters of stream health were evaluated using an EPA Habitat Assessment Field Data Sheet and each site was assigned a numerical value according to overall health. Qualitative habitat assessment data revealed that stream health was extremely poor near Auto/Rail sites, fairly poor near urban development, and quite healthy in natural areas. Thus, Alameda creek has many areas suitable for successful fish reintroduction (i.e. natural and some urban areas), but overall Alameda Creek has unsuitable physical habitat needed for thriving fish populations. Overall, the data collected strongly suggest that site-specific restoration measures are needed in order to improve the ecological condition of Alameda Creek.

Introduction

Urban development alters the natural flow and hydrological conditions of many streams. Oftentimes, these changes result in degradation of water quality, physical habitat, and biotic life of the aquatic system (Davis, Weaver, Parks, and Lydy 2002). Alameda Creek, originating at the Calaveras Reservoir, is an example of such a creek, which stretches approximately 30 miles through two large urban cities, namely Fremont and Union City, before flowing out to the San Francisco Bay. In addition, the creek also passes underneath Route 680 and Route 880; two very heavily traveled interstate highways in the Bay Area. Alameda Creek is the longest and largest creek in the East Bay Area, draining 700 square miles behind the East Bay hills. The Alameda Watershed is split between Alameda (23,000 acres) and Santa Clara (13,000 acres) Counties, which are highly populated counties that lie at the heart of Silicon Valley (Spliethoff 2002, elect. comm.). Land uses in the region include residential, light industrial, commercial, agricultural, ranch, and parklands (Gunther, Hagar, and Salop 2000). Thus, the creek is affected by a variety of human activities and the presence of large urban areas.

Urbanization expands the area of impervious surfaces in a watershed, resulting in increasing volume of surface runoff (Moses and Morris 1998). This alters the natural hydrologic pattern of the stream as heavy runoff alters natural riffles, runs, and pools, resulting in heavy sediment deposition downstream. In addition, urbanized streams are channelized and the natural meander of the creek is disrupted. For example, a 1998 study found that detrimental affects to the physical habitat of urban streams include increasing in-channel incision, bank erosion, and sedimentation and reducing substrate and channel diversity, in-stream aquatic habitat, and riparian vegetation (Moses and Morris 1998). These physical changes are detrimental to overall creek health. Not only is the physical structure of the stream affected by urban centers, but water quality and biotic diversity may also be adversely affected by urban development. For example, a recent study of Alameda Creek demonstrated that Steelhead trout have been prevented from entering the entire Alameda Creek watershed since the 1950’s when the creek was channelized in order to construct a flood control channel through Fremont, CA (Entrix, Inc., 2003). Thus, it is important to assess water quality and evaluate the physical habitat of Alameda Creek, which will hopefully provide valuable insight on the suitability of the creek for reintroduction of native fish species. Alameda Creek was chosen as this study’s focus due to its varying adjacent land uses, presence of an urbanized watershed, evidence of native fish occasionally present in the creek, and ease of access to all sites along the creek. This study's main objective is to determine whether Alameda Creek has suitable physical habitat quality for the successful reintroduction of native fish species including Steelhead trout, Coho salmon, and Chinook salmon (Scoppettone and Smith 1978). Freshwater habitat, such as Alameda Creek, is extremely important for fish spawning and rearing. Hence, it is important to consider the full life cycle of these native fish species whose habitat requirements are associated with distinct life history stages: the upstream migration of adults, spawning and rearing of juvenile, over-wintering, and eventual migration of young fish back to the ocean.

Recent studies on Alameda Creek have focused upon the amount and quality of rearing habitat available for Steelhead trout during the summer season via aerial observations. (Entrix, Inc., 2003). Other studies have focused on assessing the potential for restoring a viable Steelhead population in the entire Alameda Creek watershed including Alameda creek and its various tributaries (Gunther, Hagar, and Salop 2000). The most recent study evaluates the suitability for reintroducing Anadromous Steelhead to certain reaches and sub-samples of Alameda Creek (Hanson Environmental, Inc. 2002). The aforementioned work is produced by private corporations, which may have a vested interest in Alameda Creek. Thus, there is a need for an independent assessment of Alameda creek that will be used as a basis for comparison with existing research. Furthermore, this study's conclusions and findings will be greatly strengthened by existing recommendations, field work completed as part of this study, a review of and comparison with available data, and information in the technical literature. Therefore, a three-month study was conducted to evaluate the physical habitat of Alameda Creek using an EPA Habitat Assessment guide, as suggested for providing visual assessment of stream habitat type and quality (Barbour et al. 1999). The creek was divided into four major categories based on adjacent land use (Urban use, Auto/Rail overpass, and Natural areas) and three sites were sampled from each category for a total of nine sample sites (Appendix A). The data collected on physical habitat quality at each sample site was used to determine whether the conditions along the creek are suitable for the reintroduction of native fish species. In other words, the EPA Habitat Assessment guide assigns a numerical value to creek features such as epifaunal substrate/available cover, sediment levels, embeddedness (amount of gravel, cobbles or silt in the stream bed), etc. that are a few criteria important for fish to survive and reproduce. A higher score translates to a relatively healthier creek, which may or may not translate to the possibility of successfully reintroducing native fish species. The total score is represented as a percentage of a total possible score of 200. Collected data was then compared to native fish habitat requirements at various life history stages to evaluate whether Alameda Creek is capable of sustaining healthy fish populations. This study will not only be useful in determining the suitability of Alameda Creek for fish reintroduction, but it will also qualitatively analyze the effects of urbanization on a stream, which can then be used as a reference for similar studies in the Bay Area and nationwide where a watershed is as heavily populated and developed as the Alameda Watershed. I believe this study, in conjunction with existing research, will greatly aid in further restoration efforts and will encourage an increase in biotic diversity.

Methods

Objectives The main objective of this study is to determine whether Alameda Creek has suitable physical habitat quality for the successful reintroduction of native fish species. The methods address the "suitability" factor as data collected assigns numerical values to variables that are a measure of a stream's physical habitat. There is currently existing data on the preferred habitats of Steelhead trout, Coho salmon, and Chinook salmon (native fish species once found in Alameda Creek), and will serve as a basis of comparison to determine whether observed data at various sites along Alameda Creek proves to be suitable for any one of these native fish species (Smith 1999). However, the successful reintroduction of native fish species is beyond the scope of this particular study and will require further experimental work over successive generations of fish.

Data Collection The study site includes nine selected (explained further below) sites along the Alameda Creek, which flows for approximately 30 miles through the cities of Fremont, Union City, and Newark. Various stretches of the Alameda Creek were categorized according to adjacent land uses by observing which type of land use was most prevalent near the creek (100 feet upstream and downstream from sample location) at a particular site. These categories include 1) Urban use (i.e. housing developments, parks, playgrounds, etc.), 2) Auto/Rail overpasses (i.e. Interstate 880, local roads, BART, etc.), and 3) Natural areas (i.e. Sunol Wilderness Preserve, Coyote Hills marshland, SFPUC watershed land, etc.). Actual sampling procedure began by randomly selecting three sites from each of the three categories described above (i.e. 3 sites considered "Urban-use") for a total of nine sites. Sampling took place at the same time of day and was conducted monthly at each site over a period of three months (February – April 2004). An EPA Habitat Assessment guide was used to qualitatively assess creek habitat and to assign numerical scores to each site. The EPA Habitat Assesement Field Data Sheet assigns numerical values to each criteria (10 total) of the stream's physical habitat. In other words, the higher the score, the more "natural" and healthier is the stream. A scorecard, which described the general characteristics of the creek at the respective site as outlined by an EPA Habitat Assessment guide, was created for each of the nine sites.

For the statistical analysis, a one-way ANOVA test was used to look for differences in habitat assessment scores amongst the three different adjacent land use zones. This test was then followed by a one-way repeated-measures ANOVA test to determine whether the differences were attributable to the different land use zones or whether they arose from monthly changes at the sample sites. The data was then analyzed in relation to habitat requirements of native fish species at various life history stages.

Results

The three "Urban" zone creek sites sampled include 1) Ardenwood Blvd. housing development, 2) Whitehead Place housing development, and 3) Niles Community Park. The three "Auto/Rail" zone creek sites sampled include 1) Interstate-880 overpass, 2) Mission Blvd. bridge, and 3) BART weir/overpass. The three "Natural" zone creek sites sampled include the 1) Niles Canyon, 2) Sunol Regional Wilderness (A), and Sunol Regional Wilderness (B – located near headwaters) areas.

A one-way ANOVA test comparing habitat assessment scores from the three land use regions show a significant difference amongst the three groups of land type. The calculated F-value was 28.88, which was greater than the F-critical value and p=0.0013. Figure 1 shows the average overall creek health score at each of the three different adjacent land use zones. The data collected show that the natural land zones had a significantly higher physical habitat than habitat quality found at auto/rail overpass and urban land zones.

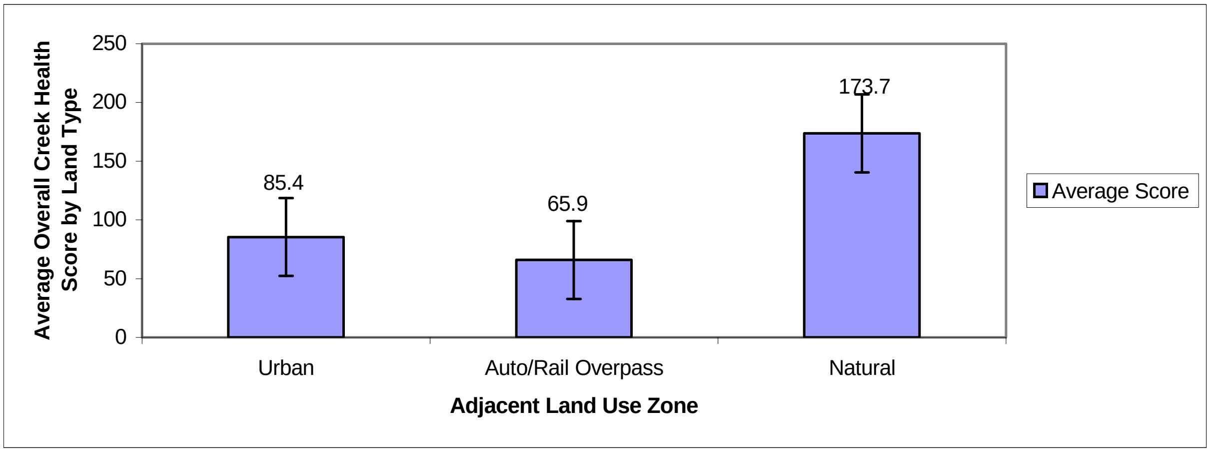

Figure 1. Histogram of the mean habitat assessment scores of each of the adjacent land use zones. A one-way ANOVA showed a significant difference (p=.0013) in overall creek health amongst the three different land use zones. It is evident that the natural areas had a significantly higher quality physical habitat than those found at both urban and auto/rail overpass areas.

A one-way repeated-measures ANOVA test comparing habitat assessment scores from the three land use regions on a monthly basis still showed a significant difference amongst the three groups of land type. The calculated F-value was 77.49, which was greater than the F-critical value and p=0.0005. Figure 2 shows the overall habitat assessment score at each sample site by month. The statistical test indicates that month-to-month variation was not significant.

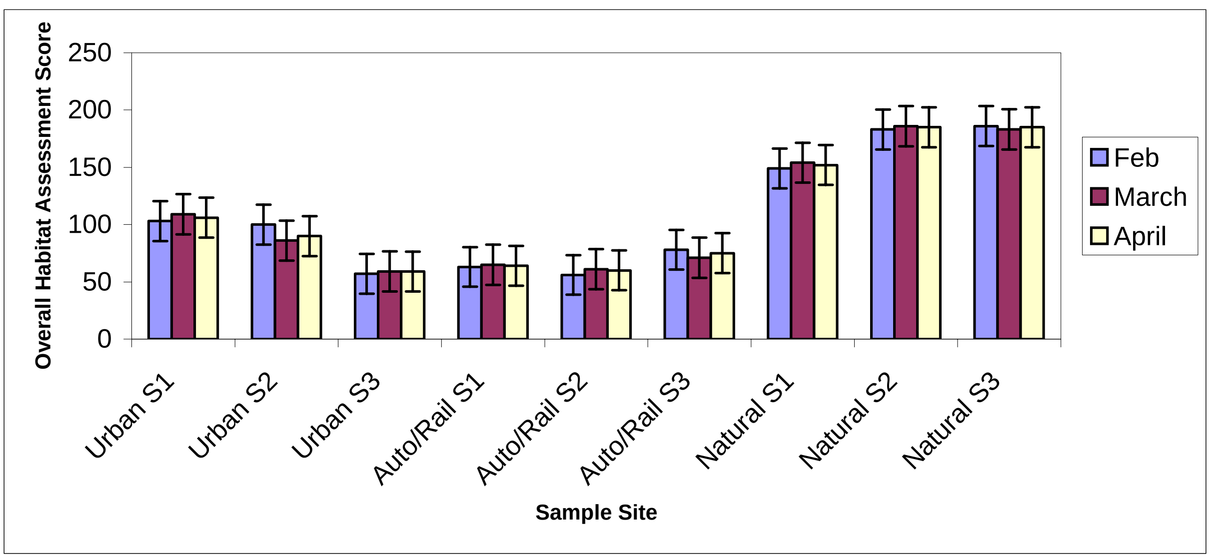

Figure 2. Histogram of the overall habitat assessment score at each sample site by month. A one-way repeated-measures ANOVA showed a significant difference (p=.0005) between the habitat assessment scores amongst land use zones suggesting that month-to-month variation was not significant.

It is important to note that the poor habitat assessment scores seen in both urban and auto/rail overpass areas are attributable to the following main habitat parameters: 1) lack of epifaunal substrate/available cover, 2) completely altered channels, and 3) poor vegetative protection and low riparian vegetative zone width (Fig. 3).

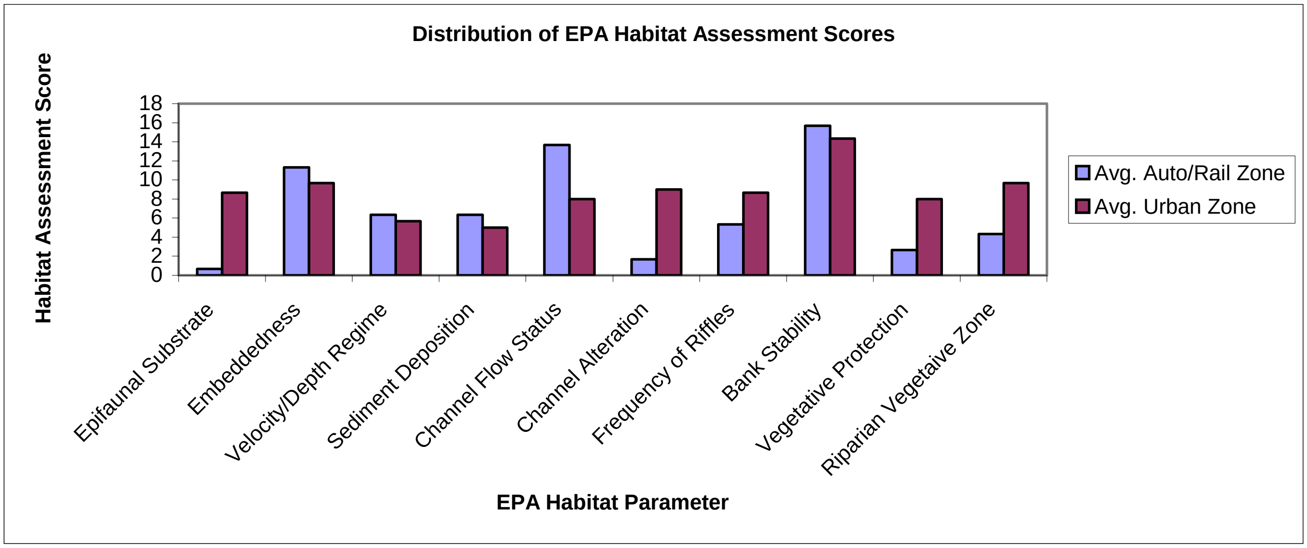

Figure 3. Histogram of distribution of EPA habitat assessment scores. Data show that Auto/Rail land zones and Urban land zones have relatively lower scores for epifaunal substrate, channel alteration, vegetative protection, and riparian vegetative zone.

Discussion

Adjacent land use to Alameda Creek significantly affects the physical habitat quality of the creek and also affects the local ecosystem. Native fish species such as Steelhead trout, Coho salmon, and Chinook salmon require specific habitat types and quality throughout their life history stages, especially while spawning and rearing young (Levy and Slaney 1993). The results show that according to the EPA Habitat Assessment criteria, the natural land zones adjacent to Alameda Creek have very high creek health. However, urban and auto/rail overpass land zones have significantly poorer creek health, while the auto/rail land zone has the worst physical habitat of all three types of adjacent land zones. Thus, physical habitat quality is quite variable along the course of Alameda Creek, as these three land zones occur at various, alternating sites. A detailed map, which highlights the nine sample sites and physical habitat quality scores at each site, is shown in Appendix A.

It is important to note that the most recent studies performed on Alameda Creek evaluated physical habitat type and quality. However, these studies did not use the EPA Habitat Assessment Field Data Sheet (HAFDS) method, but instead relied on other observational methods including an aerial observation as performed by Entrix, Inc. in 2003. The rationale for using the HAFDS method is that it is cost-effective, sufficiently valid, provides for multiple site investigations, has a quick turn-around of results for management decisions, and has environmentally-benign procedures (USEPA 2004, elect. comm.). However, the HAFDS method has its limitations, as it is heavily dependent upon the subjectivity and training of the individual applying these methods (Ward et al. 2003). Furthermore, it is important to note that the HAFDS outcome scores are calculated as the average of scores for each question in the assessment, giving each question equal weight for the final outcome (Ward et al. 2003). In this study, this is problematic, as successful native fish reintroduction is more heavily dependent on some habitat parameters (i.e. vegetative/escape cover) than others (i.e. sediment deposition). However, the HAFDS method is scientifically reliable and provides useful methods for assessing Alameda Creek and its suitability for reintroducing native fish species.

Steelhead trout, Coho salmon, and Chinook salmon utilize various aquatic habitats. Freshwater streams, such as Alameda Creek, are particularly important habitats for such fish to utilize for spawning and juvenile rearing (Levy and Slaney 1993). Thus, it is important to understand fish life history when evaluating habitat requirements needed for successful reintroduction and survival. The following sections address fish life history stages and associated habitat requirements.

Upstream Migration of Adults Chinook salmon (Sep. – Nov.), Coho salmon (late Nov. – mid-Feb.), and Steelhead trout (late Dec. – April) adults migrate upstream from the San Francisco Bay in order to spawn. All three species require sufficient stream-flow to provide passage over shallow riffles, log jams, falls, etc. (Smith 2003). All three land use zones in Alameda Creek fulfill these required habitat characteristics, as there is plenty of rain in the Bay Area to maintain sufficient stream-flow. However, man-made barriers such as dam and culverts are a major problem within Alameda Creek that prevent fish from migrating upstream. In particular, there are two major dams located along the creek that the aforesaid fish cannot jump over or swim around (Appendix A). The majority of fish are able to swim up till the BART Weir where a large rubber dam restricts natural stream-flow. This is a significantly large area where stream flow is inadequate for fish migration. In fact, the Alameda Creek Alliance has documented several Steelhead trout trying to jump over this area during the migration season. Alameda Creek does not have suitable habitat for upstream migration of adults, because the migration is restricted by two dams: 1) BART Weir and 2) Calaveras dam located near the headwaters. Existing research supports these findings, actually identifying several other structures impeding upstream fish migration including a natural gas pipeline located in the Sunol Valley and a few other inflatable dams along the course of the creek (Gunther, Hagar, and Salop 2000).

Spawning (Reproduction) Chinook salmon (Sep. – Dec.), Coho salmon (late Dec. – Feb.), and Steelhead trout (late Dec. – April) adults reproduce within freshwater habitats after successfully migrating upstream. All three fish species require sufficient cool stream-flow, clean pea to apple-sized gravels, riffles and deep pools, and cover needed for escape (Smith 2003). The natural land zones adjacent to Alameda Creek provide favorable habitat that meet the needs of spawning fish. However, heavy channelization and damming have limited these zones to only slow-moving deep pools. Consequently, the auto/rail overpass and urban land zones lack escape cover and much-needed riffles. In fact, all three of the auto/rail overpass sites have minimal to no cover. Furthermore, heavy road construction and repair at these three sites also creates siltation of gravels that may result in smothered eggs. The only suitable sites for fish spawning are located in the natural land zones adjacent to Alameda Creek. Additionally, two of the urban sites may provide the needed habitat but would require experimental testing. Therefore, the work performed by Hanson Environmental, Inc. in 2002 is extremely valuable as they actually attempt to reintroduce Steelhead populations to specific reaches where suitable habitat is prevalent (Hanson Environmental, Inc. 2002).

Rearing Chinook salmon (3-6 months), Coho salmon (1 year), and Steelhead trout (1 or 2 years) rear their young (smolts) within freshwater habitats such as Alameda Creek. In fact, favorable habitat quality is essential to this life stage in which numerous other factors limit survival such as predation, intra-specific competition for food and cover, and other density-dependent processes (Levy and Slaney 1993). All three fish species require sufficient escape or hiding cover (undercut banks, logs, pools, etc.), fast-water feeding areas, and productive pools for growth and development (Smith 2003). Again, the natural land zones adjacent to Alameda Creek provide extremely favorable habitat. However, the auo/rail overpass and urban zones do not meet the rearing habitat requirements as escape cover is extremely limited and fast-water feeding areas are scarce. However, all three land use zones offer favorable pools for juvenile growth.

Overwintering Chinook salmon, Coho salmon, and Steelhead trout spend winter within freshwater habitat before migrating to the ocean. The smolts' major requirements during this life stage are deep pools and good escape cover (Smith 2003). As mentioned earlier, favorable escape cover is only present in the natural land zones adjacent to Alameda Creek where deep pools are also quite frequent. The fish are extremely dependent upon such factors for protection from high stream-flow and flooding.

Migration of Juvenile Fish to the Ocean Chinook salmon, Coho salmon, and Steelhead trout young return to the ocean to live out their adult lives. The most critical habitat requirement at this life history stage is sufficient stream flow to allow safe passage back to sea (Smith 2003). Unfortunately, this study was performed during the late winter to early spring months (Feb-April) and thus did not evaluate Alameda Creek during the summer months when native fish species would migrate back to the ocean. However, in-depth studies performed by Entrix, Inc. in 2003 found that Alameda Creek lacks sufficient stream flow needed for out-migration and also recommends the removal of man-made barriers such as the inflatable dam found at the BART Weir (Entrix, Inc. 2003).

Conclusions Alameda Creek, as a whole, does not have all the necessary habitat requirements needed for the successful reintroduction of native fish species. In particular, the creek especially lacks favorable velocity/depth regimes, as usually only two of the four habitat regimes are present (i.e. slow-deep, slow shallow). Furthermore, the creek especially lacks available escape cover, and there is little to no epifaunal substrate or cover at auto/rail overpass sites and semi-favorable cover at urban sites. It is important to note that the natural land zones offer favorable habitat that meets all three species' requirements at each life history stage. Thus, Alameda creek has many areas suitable for successful fish reintroduction (i.e. natural and some urban areas), but overall Alameda Creek has unsuitable physical habitat needed for thriving fish populations. However, the aforementioned parameters of fish habitat are not of equal importance, as a sufficient amount of breeding and rearing habitat will allow for fish to reproduce and grow, but even the slightest barrier to upstream and downstream fish migration will lead to a complete lack of survival and unsuccessful attempts to reintroduce native fish species. In totality, the data collected strongly suggest that site-specific restoration measures are needed in order to improve the ecological condition of Alameda Creek. In particular, dams need to be removed in order for fish to successfully migrate upstream. These findings are supported by exiting research, which used methods different from this study, and also recommend site-specific restoration of man-made barriers. Alameda Creek also needs to provide plenty of vegetative/escape cover and simply removing impeding barriers will not be enough to sustain native fish populations. This study recommends that native plants species are restored to the banks of Alameda Creek and restoration efforts include developing favorable habitat for native fish species.

Moreover, this study only qualitatively assesses physical habitat required for native fish reintroduction and survival. Further studies are needed to experimentally address whether native fish species can truly survive and reproduce within Alameda Creek. Additional work is required to analyze water chemistry, as native fish species require very specific water temperatures and dissolved oxygen levels, etc. A macroinvertebrate assessment is also needed to further evaluate creek health and to determine if there is ample food for thriving fish populations. This study provides both a basis for comparison with existing research and a sound base for further work. It can be used as a reference for similar studies in the Bay Area and nationwide where a watershed is as heavily populated and developed as the Alameda Watershed. This study will greatly aid in further restoration efforts, encouraging an increase in biotic diversity through further research.

Acknowledgements

Special thanks to Renata Andrade for her assistance and encouragement. This paper would not have been possible without her dedicated support. I would also like to thank Professor John Latto and Professor Donna Green for their much-needed guidance, patience, and support throughout the ES 196 year.

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Appendix A: Alameda Creek Sample Sites