Supplementation Alternatives for Restoration of a Viable Steelhead Run to Alameda Creek

Prepared for:

California State Coastal Conservancy
1330 Broadway, 11th Floor
Oakland, California 94612-2530

On behalf of:

Alameda Creek Fisheries Restoration Workgroup

Prepared by:
Hagar Environmental Science
6523 Claremont Avenue
Richmond, California 94805

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1 *Background*

The Alameda Creek Fisheries Restoration Workgroup (Workgroup) was established in 1999 to explore the feasibility of restoring a steelhead run to Alameda Creek. The Workgroup completed a feasibility evaluation and concluded that there were regions of the watershed with suitable habitat to support steelhead; that there were resident rainbow trout in the watershed and a few returning steelhead that had genetic characteristics similar to other wild stocks of coastal steelhead; and that the presence of several structures form migration barriers that prevent steelhead from using the Alameda Creek watershed (Gunther et al 2000). Based on these findings the Alameda County Flood Control and Water Conservation District and Alameda County Water District have applied to the U.S. Army Corps of Engineers for funding to provide passage improvements at several of the most significant migration barriers.

As part of its feasibility assessment, the Workgroup has recognized that several additional actions may be needed to accomplish restoration of a steelhead run. Peer review comments on the feasibility assessment suggested that initially a few steelhead may return to Alameda Creek once access is provided, but that unless the offspring of these few fish is supplemented in some way, there may be undesirable consequences due to the initial low genetic diversity of a small founder population. Resident trout populations exist in the upper part of the watershed in Alameda Creek, Arroyo Mocho and areas that are isolated upstream of San Antonio and Calaveras Reservoirs (Smith 1998; Gunther et al. 2000). These populations may retain anadromous characteristics and may provide a genetically appropriate source for supplementing a steelhead run in Alameda Creek. Supplementation using stock native to the watershed is desirable for preservation of genetic diversity. If Alameda Creek stocks are not suitable for supplementation (due to interbreeding with introduced hatchery stocks, low abundance, or other reasons) then stocks from other watersheds may be considered.

Previous genetic analyses conducted by Nielsen (1999) have supported a close genetic relationship between trout found in Niles Canyon and below the BART weir on Alameda Creek with coastal trout found in Marin County. These analyses found no significant associations among Alameda Creek trout and fish collected from four primary rainbow trout hatchery strains used for stocking streams in California. These analyses did not include trout from the four main headwater areas of Alameda Creek that may provide a source for initiation or supplementation of an Alameda Creek steelhead run.

The present work was undertaken to expand genetic analyses to previously un-sampled parts of the Alameda Creek watershed and to provide an initial discussion of the potential for use of these populations in a supplementation program. Restoration of a steelhead run in Alameda Creek will involve further consideration of fish genetics and population dynamics with input from those with extensive expertise in these areas. For example, there is significant scientific uncertainty as to the nature of undesirable consequences due to initial low genetic diversity of a small founder population. It will be important to determine the optimum initial size and genetic source of founder populations, and it is likely that such a determination will be somewhat experimental. This report is intended to provide a summary of relevant information collected to date in the Alameda Creek watershed, to explore the parameters for a successful supplementation program, and lay a conceptual groundwork for further development of supplementation efforts.

During the spring of 2001, tissue samples were collected from resident steelhead/rainbow trout (*Oncorhynchus mykiss*) in upper parts of the Alameda Creek watershed for genetic analysis and evaluation of likely genetic ancestry of the populations (Hagar 2002). In addition, the sampling provided some additional information on the status and distribution of resident rainbow trout populations in the watershed. Two areas were sampled by electrofishing including Arroyo Mocho southeast of Livermore and upper Alameda Creek upstream of the Calaveras Creek confluence. Trout in upper Alameda Creek and Arroyo Mocho are isolated from the ocean by migration barriers and do not have access to downstream reservoirs. Anadromous traits may have been lost in these populations. Tissue samples were also collected as part of a monitoring program conducted by the San Francisco PUC on San Antonio Creek upstream of San Antonio Reservoir and on Arroyo Hondo upstream of Calaveras Reservoir.

Sampling in Arroyo Mocho was conducted on the property of J. Norton on April 17, 2001. Sampling in upper Alameda Creek was completed on May 11, 2001 in the Little Yosemite area, a second location downstream of the Alameda diversion dam and a location upstream of the dam. Fish were collected using backpack electrofishing equipment. Upon collection, a small portion of each caudal fin was clipped and placed in individually labeled sample envelopes for transport to the analytical laboratory. Once the tissue samples were collected, the fish were returned to the stream reach from which they were found. A summary of electrofishing results is included in Table 1.

Table 1. Rainbow trout from selected regions of Alameda Creek watershed, spring 2001

	Alameda Ck. above Alameda Diversion	Alameda Ck. below Alameda diversion	Alameda Ck. at Little Yosemite	Arroyo Mocho on Nolan Property
Number *O. mykiss*	5	9	16	31
Minimum Length (mm fork)	120	105	99	89
Average Length (mm fork)	139	138	129	129
Maximum Length (mm fork)	160	218	191	189

note: external dark spots attributed to trematode infections ("black spot disease") widespread in trout at all sample sites.

The SFPUC is currently conducting an evaluation of landlocked steelhead populations in San Antonio and Calaveras Reservoirs, two of the primary headwater areas supporting trout (ENTRIX, Inc. 2002). Both areas support populations of *O. mykiss* that appear to have retained anadromous traits. Adults reach relatively large size in the reservoirs and share external characteristics with steelhead including a silver coloration. In the winter they ascend tributary streams to spawn and their progeny return to the reservoir as fry or older juveniles. The study involves trapping trout as they migrate downstream to the reservoirs during the spring smolt emigration period. Arrangements were also made to collect tissue samples from fish captured in the traps. Fish length and condition, including any indication of smoltification, were noted for each sample.

Tissue samples collected in both the electrofishing survey and the reservoir tributary trapping were analyzed by Dr. Jennifer Nielsen at USGS in Anchorage, who has developed an extensive database of genetic information for steelhead/rainbow trout in Central California and other areas. Dr. Nielsen compared genetic characteristics of tissue samples with those of previously evaluated known populations of steelhead from both and hatchery and wild populations (Nielsen 2003). A copy of Dr. Nielsen's report is included as Appendix A to this report.

The results of Dr. Nielsen's analyses indicated that, with the exception of fish collected in Arroyo Mocho, resident trout in the Alameda Creek watershed were more closely related to each other than to any reference collection used in the analyses and that their closest genetic relationship was found with fish collected in Alameda Creek in 1997-1999, including adult steelhead captured downstream of the BART weir. The closest out-of-basin genetic relationship for all year classes of Alameda Creek trout (excluding Arroyo Mocho) was with steelhead collected from Lagunitas Creek, Marin County (Nielsen 2003). Dr. Nielsen concluded that resident populations of trout in Alameda Creek would make good candidate populations for supplementation of the anadromous runs in the lower watershed, provided they demonstrate the ability to migrate and survive at sea (Nielsen 2003). Both the San Antonio and Arroyo Hondo populations retain anadromous characteristics and life-history seasonality consistent with coastal steelhead stocks. Dr. Nielsen's analyses showed Arroyo Mocho trout to be more closely related to hatchery fish from the Whitney Hatchery strain but she cautioned that this genetic association does not preclude the possibility that Arroyo Mocho trout represent a long-standing natural resident trout population derived from the same ancestral source population as the fish used to found the Whitney Hatchery strain.

3 Supplementation Plan Alternatives

The primary objective of supplementation is to maximize the return of genetically suitable adults to the Alameda Creek watershed. The most genetically suitable *O. mykiss* are likely to be those descended from native coastal steelhead in Central California coastal streams. Genetic diversity is also an important consideration and maximizing returns should not adversely compromise genetic diversity. It is also important that anadromous traits have been retained in a potential donor population. An additional objective is that any donor population should not be adversely effected by the supplementation effort. Removal of individuals from donor populations should only occur at a level that does not threaten the sustainability of donor populations. Also, the program should maximize efficiency and minimize loss of fish by ensuring capture of large numbers of individuals, minimizing holding and transport time, minimizing handling, and maximizing return potential.

There are several ways that a supplementation program could use fish from the San Antonio and Calaveras Reservoir populations. Smolt or partial smolt stage *O. mykiss* could be captured during their emigration to the reservoirs, and transported for release in lower reaches of Alameda Creek. *O. mykiss* fry, young-of-year, and parr could also be collected on their downstream migration to the reservoirs and either released in suitable rearing habitat downstream of Calaveras Reservoir or transported to a temporary rearing facility, reared to smolt stage, and released. Adult *O. mykiss* could be captured during the spawning run and introduced to suitable spawning habitat in downstream reaches. Alternatively, adult fish could be captured and artificially spawned and their offspring could be hatched and reared in a temporary facility or hatched and released to suitable sections of Alameda Creek. The advantages, disadvantages, and efficacy of each approach are discussed in the following sections.

3.1 Transplantation of smolts

Release of salmonid smolts is a common management tool for increasing runs. Much of the Central Valley hatchery production of chinook salmon is released as smolts at various locations between the hatcheries and San Francisco Bay. The central question to address under this scenario involves how many smolts would be needed to make the program work and how many smolts could be skimmed from reservoir populations without threatening the continued existence of those populations. There is also a tendency for hatchery reared smolts to residualize (not migrate and become resident) after release. This may also be a problem with trapped smolts although these fish would be captured while moving downstream and would be released within a short time. They may behave differently than hatchery reared smolts.

Use of smolts from San Antonio and Calaveras Reservoirs would require trapping of smolts migrating downstream into the reservoirs, transport in chilled and aerated conditions, and release in the lower watershed. Capture, transport, and release would be conducted on a daily basis beginning with the onset of smolt migration (presumably in March) and continuing as long as conditions in lower Alameda Creek were suitable for release. Based on on-going migrant trapping studies conducted by the SFPUC, San Antonio Reservoir has advantages over Calaveras Reservoir in terms of greater numbers of smolts, easier access, and shorter transport time. Use of fish from both reservoirs would be advantageous from the perspective of maximizing genetic diversity in the reconstituted run.

The release would need to occur at an appropriate time and under appropriate environmental conditions. Steelhead smolts typically migrate from streams in Central California in March, April, and May. Given warmer temperature conditions and declining stream flows in Alameda Creek as the spring progresses, it would be desirable to complete releases in March and early April. The release location should maximize both potential for survival to the ocean and the probability of return to Alameda Creek. Altered conditions in the lower reaches of Alameda Creek may result in increased water temperature, reduced flow rates, and increased susceptibility to predation on migrating smolts and release locations closer to San Francisco Bay are likely to enhance survival probability. However, releases at locations closer to potential spawning and rearing habitat in Alameda Creek below Little Yosemite are likely to have lower straying rates and greater potential for return. Releases at both locations may be appropriate and could be used to generate useful information concerning potential mortality rates and straying potential for emigrating fish.

The number of smolts needed depends on the target number of adults returning in the initial spawning run. How large would an initial steelhead run have to be to minimize the risks associated with small founder populations and maximize the potential for a viable population? This question is particularly important since it is possible that existing reservoir populations were originally founded by a relatively small number of *O. mykiss*. Population viability depends not only on abundance but also on population growth rate, spatial structure, and diversity (McElhany et al. 2000). NOAA Fisheries defines a viable salmonid population as an independent population that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100 year time frame (McElhany et al. 2000). It is not within the scope of this work, nor is there presently sufficient information, to determine a theoretically viable steelhead population size for the Alameda Creek watershed. Still, there is something to be learned by examining the potential number of smolts available in the reservoir populations and evaluating the potential for returns to Alameda Creek.

During trapping of fish moving downstream into San Antonio Reservoir in late winter and spring of 2002, 219 *O. mykiss* in partial smolt and smolt condition were captured (ENTRIX, Inc. 2003). In the Arroyo Hondo trap upstream from Calaveras Reservoir, a total of 151 partial smolt and smolt *O. mykiss* were captured (ENTRIX, Inc. 2003). Smolt production in these tributaries may vary significantly from year to year and until further monitoring is completed, there is no way to know whether these numbers are typical. It is also possible that the present trapping program is not the most efficient for smolt-size steelhead and that improvements in the trapping methods would result in higher numbers of smolt captures. There has been some discussion within the workgroup that improvements to the trap may be necessary to obtain higher capture rates, particularly for smolts. For the sake of argument, let us assume that up to 50% of these individuals could be removed from the population without jeopardizing its continued existence. This number may be slightly on the high side but is useful for illustration. If 50% of the smolts were used from each reservoir, that would have made about 185 smolts available for supplementation in lower Alameda Creek during 2002.

Shapovalov and Taft (1954) marked juvenile steelhead on their downstream migration from Waddell Creek and estimated overall survival from returns of these marked fish in the adult steelhead spawning run. Returns ranged from 1.7% to 6% and averaged 3% for the five years evaluated. These estimates may be conservative since: (1) a number of downstream migrants actually remained in downstream reaches without migrating to sea for an additional season and would have experienced additional mortality before going to sea; (2) there was likely some loss of adults in the ocean due to fishing; and (3) not all returning adults were checked for marks (some spawned downstream of the trapping station and some by-passed the trapping station during high flow conditions). On the other hand, smolts leaving Waddell Creek enter the ocean directly while those leaving Alameda Creek, depending on the release location would have to traverse a length of flood control channel and migrate through the South Bay to reach the ocean and may experience higher initial mortality rates.

Using the 3% return as a best guess estimate, a release of 185 smolts in Alameda Creek may be expected to produce a return of 6 steelhead. This would not seem to be a sufficiently large run to meet the objectives of a supplementation program, however this conclusion is based on limited results and may not reflect the true potential if higher numbers of smolts can be captured. For example, it may be possible to use different gear to sample higher flows when present methods are inefficient or impractical.

3.2 Transplantation of fry, young-of-year, and parr

Substantial numbers of *O. mykiss* fry, young-of-year, and parr migrate from tributary spawning areas downstream to San Antonio and Calaveras Reservoirs in the spring. In the spring of 2002, the SFPUC trapping study collected over 800 of these fish from San Antonio Reservoir tributaries and over 900 from Calaveras Reservoir tributaries. The majority of these fish were young-of-year. These fish typically experience very high mortality rates by the end of the summer in stream habitats. Although no information is presently available that would allow determination of their survival rates in the reservoir or their importance in maintaining the reservoir populations, it could be argued that this is the most expendable life-stage. It may be possible to use the entire catch of parr and younger *O. mykiss* in a supplementation program without jeopardizing the reservoir populations.

If juvenile *O. mykiss* were introduced to suitable rearing habitat in lower Alameda Creek, it is likely that they would experience low rates of survival as is typical for this life-stage in stream environments. The stress involved with capture, handling, and transport as well as the vulnerability involved with introducing these fish to a novel environment would likely result in even lower rates of survival.

In their studies of *O. mykiss* in Waddell Creek in the 1930s, Shapovalov and Taft (1954) were able to estimate overall survival rates of *O. mykiss* from egg to return of adults spawning for the first time (survival to subsequent spawnings was not included). They found that in the five years for which estimates were possible that this survival rate ranged from 0.017% to 0.029% and averaged 0.023%.

For a stable population, the average number of returning adults is relatively constant over time and, although there may be wide annual variations, on average one female steelhead eventually returns for every female that spawns. This is somewhat complicated by the fact that a certain proportion of female steelhead spawn more than once. In long term studies at Waddell Creek (Santa Cruz County) first time spawners made up about 83% of the run on average (Shapovalov and Taft 1954). Ignoring repeat spawners for now, if sex ratios are 1:1 then, on average, 2 returning steelhead must be produced by each female spawner. In Waddell Creek the actual sex ratio among first time spawners averaged very close to 1:1 (Shapovalov and Taft 1954). An average sized adult female steelhead of 23 inches may be expected to carry about 5,000 eggs. If half of those eggs produce females, the overall loss between egg and first returning adult female in a stable naturally spawning population is expected to be 2,499/2,500 or about 99.96%. Conversely, long-term average survival to first spawning in a stable steelhead population is estimated at about 0.04%. Survival rates estimated by Shapovalov and Taft were therefore slightly below replacement level although accounting for repeat spawning would have brought them closer together. It would not be unexpected for actual measured rates in any year to be above or below replacement level in a stable population since it is the long-term average that is important.

It is possible to estimate survival from the emergent fry stage to returning adult by backing out the egg to fry losses from Shapovalov and Taft's estimate of egg to adult survival. Survival from egg to emergence can be extremely variable depending on environmental conditions. Shapovalov and Taft concluded that under favorable conditions in good habitat survival to emergence is expected to be fairly high and they estimate that in Waddell Creek it ranges from 70% to 85% of the eggs deposited. Using the 70% rate to estimate the upper end of potential survival during the later stages (assuming good habitat and favorable environmental conditions) it is estimated that a rate of 0.032% (0.023% divided by 70%) may be a reasonable expectation for average survival from fry to returning spawner for a stable population in good habitat and under reasonably good environmental conditions.

O. mykiss designated as young-of year captured in the downstream migrant traps during the February to May trapping period generally would have emerged from redds within the past few weeks but may be 2 to 3 months old. Some mortality would have occurred during the period since emergence, so using the fry to adult spawner survival rate based on the Shapovalov and Taft data would result in an underestimate of survival for these slightly older fish. The difference is likely to be fairly small and may be compensated by additional mortality due to capturing, handling, transport, and relocation.

Assuming that all 1,700 fry, young-of-year, and parr were relocated to suitable rearing habitat in lower Alameda Creek and that they experienced survival rates comparable to the Waddell Creek population studied by Shapovalov and Taft, we would expect an initial return of something like 0.032%, or less than 1 first time spawner. This obviously fails to meet the supplementation objectives if numbers of *O. mykiss* available in 2002 are representative of typical conditions.

Rather than release captured juvenile *O. mykiss* to the natural stream environment, an alternative approach would be to rear them in a controlled environment where survival rate to the smolt stage could be greatly enhanced. The Monterey Peninsula Water Management District (MPWMD) has operated a program like this in the Carmel River since 1997. The Sleepy Hollow Steelhead Rearing Facility (SHSRF) was built and is operated by the MPWMD below San Clemente Dam as part of the District's Water Allocation Mitigation Program. At the beginning of each dry season, the District rescues juvenile steelhead from sections of the Carmel River that dry up. The fish are held at the facility over the dry season and released in the fall. The facility, which includes a diversion and pump station, three large circular tanks, and 800-foot long rearing channel, electrical, water, pressurized air and drainage systems, an office/shop/lab building, and miscellaneous equipment, was completed in 1997 (MPWMD 1999). The facility has been upgraded with a cooling system and pump improvements and continues to be modified for improved production. Most of the problems encountered in developing the facility have been solved (Dave Dettman, MPWMD, personal communication, February 2004), although it has taken 6 years of improvements and experimentation to reach current production levels. In 2003, approximately 28,500 fish had been stocked in the facility by the end of August. Approximately 12,000 were released by January 2004. Approximately 25% to 30% of these were large enough to smolt by spring. Fish are held under quasi-natural conditions and obtain some natural food in the rearing channel although food is supplemented. Apparently some fast growing fish become cannabalistic in the channel and contribute substantially to the mortality rates over the rearing period (Dave Dettman, MPWMD, personal communication, February 2004).

A facility for supplementation on Alameda Creek could hold fish until spring and release them as smolts. With supplemental feeding, fish could potentially be reared to smolt size in one year. Alternatively, conditions in Niles Canyon may be suitable for good rearing during the cooler winter months, and parr could be released there for additional rearing before smoltification in the spring. If survival rates of 40% could be achieved in such a grow-out facility it could potentially produce as many as 680 smolts from the 1,700 juveniles captured during 2002. Based on the estimated 3% smolt to adult return rate described above, those smolts could produce about 20 returning first time spawners. This would be a better return than either transplantation of smolts or transplantation of juveniles to stream habitat. Potential drawbacks of this approach include a potentially lengthy period of facility development to reach necessary production levels and potential loss of fitness due to rearing under high densities in an artificial environment with artificial food.

It may be possible to "rent" or "borrow" excess rearing capacity in an existing hatchery. The Big Creek/King Fisher Flat hatchery has extra capacity in some years, which might be used. The fixed cost is the one employee who is there regardless of the number of fish raised. The hatchery is used for coho (which are absent or scarce in some years) and steelhead (which may be reduced or phased out) (J. Smith, San Jose State University, personal communication, March 2004). This alternative would require separate holding facilities for Alameda Creek fish and out-of-basin rearing may lead to higher straying rates.

Yet another approach suggested by a Workgroup member would also use natural production from streams tributary to the reservoirs but would involve structural facilities that would allow streamflow and fish to pass through the reservoir into the channel downstream (similar to a reservoir spill without waiting for the reservoir to be over topped). On storm events during the winter and spring, a portion of flow and fish could be allowed to continue migrating through the reservoir and seed areas downstream of the dams.

3.3 Capture and Transport of Adults

Adult *O. mykiss* could be captured during the spawning run and introduced to suitable spawning habitat in downstream reaches. The two main drawbacks to this option are: (1) capturing enough adults to overcome the limitations of a small founder population without jeopardizing donor populations; and (2) potential mortality due to the stress imposed from capture, handling, and transport, on fish in spawning condition .

Recent trapping surveys conducted by the SFPUC have resulted in capture of 70 adults migrating out of San Antonio Reservoir and 5 out of Calaveras Reservoir into Arroyo

Hondo during 2002 (ENTRIX, Inc 2003). At San Antonio Reservoir, 80% of upstream migrating adults were female and only 20% were male. While numbers of upstream migrating adults from Calaveras Reservoir was very low, 260 adult *O. mykiss* were captured migrating downstream to the reservoir from Arroyo Hondo. It is possible that many more adults had migrated upstream into Arroyo Hondo before trapping was initiated in February. Total spawning populations for both reservoirs combined were therefore between 75 and 330 fish. The proportion of the total population of adult *O. mykiss* that spawns in any given year is unknown but the SFPUC is in the process of developing *O. mykiss* population estimates for each reservoir. Initial estimates indicate that these populations may number less than a few hundred fish in each of the reservoirs (Brian Sak, SFPUC, personal communication, February 2004).

Reservoir populations of *O. mykiss* represent a unique and valuable resource both in terms of the behavioral and genetic diversity of the species and as a source for reconstituting a locally adapted steelhead run in Alameda Creek. Removal of individuals from the reservoir populations should be managed in such a way that viability of reservoir populations is not threatened. This requires knowledge of the population size and dynamics of the reservoir populations that is presently incomplete. Ideally, a population model would be constructed reflecting population dynamics of reservoir populations that would allow evaluation of the influence of removing various proportions of different life-history stages.

In the absence of detailed knowledge of population dynamics for these populations, a "safe" removal rate for adult *O. mykiss* of 10% of the spawning run has been assumed for the purpose exploring alternative supplementation plans. Populations of *O. mykiss* in both San Antonio and Calaveras Reservoir are not subject to any form of harvest. Removal of fish for a supplementation program would occur for a very limited duration, perhaps 5 years or less. Many salmonid populations can sustain harvest rates in excess of 10%. A 10% removal rate would allow capture and transplantation of between 7 and 33 individuals. At the lower end this would achieve an initial spawning run size not much better than the smolt transplantation alternative, but at the upper end could exceed projections for transplantation and artificial rearing of juveniles. This alternative would also be beneficial in terms of natural mate selection by adult spawners, good imprinting of juveniles for lower straying potential, and increased fitness related to natural rearing.

3.4 Use of Artificial Spawning and Rearing

As an alternative to releasing adult *O. mykiss* from reservoir spawning populations into suitable spawning habitat, another option would be to capture adults and artificially spawn the adults, hatch the eggs and rear juveniles to smolt size in the controlled environment of a hatchery, and release a relatively large number of smolts in Alameda Creek. This alternative would avoid potential problems with handling and transporting adult fish in spawning condition and releasing them in unfamiliar surroundings; however, it would involve construction and operation of potentially costly facilities for hatching and rearing. It could also be based on a relatively low number of adults. A similar program operated by the Monterey Bay Salmon and Steelhead Project (MBSSP) has been run successfully for a number of years on Scott Creek in Santa Cruz County.

Traditional hatchery programs operate by harvesting eggs from returning adults and rearing them to various stages within the controlled environment of the hatchery. This maximizes the number of juvenile salmonids that are produced from the available eggs by ensuring high hatching rates and high survival and rapid growth after hatching. A hatchery can be a major investment in both facilities and operations although some small hatchery programs have been developed on a small scale using restoration funds, donations, and volunteers. A supplementation program on Alameda Creek would be temporary and costs and effort for a hatchery program may not be justified if other supplementation opportunities are available.

Based on SFPUC migrant trapping results for 2002, a total of 70 adult *O. mykiss* were captured migrating upstream from San Antonio reservoir, however only 19 of these were ripe females. At Calaveras Reservoir, only 5 adults were captured and only one of these was a ripe female. However, 153 spent females were captured migrating downstream to Calaveras Reservoir following spawning. Earlier initiation of trapping, particularly at Arroyo Hondo, may have provided significantly more ripe spawners, potentially as many as about 170 total for both reservoirs. Average length of adults was about 18 inches. Assuming equal sizes of males and females and based on fecundity of 18-inch steelhead trout in Waddell Creek measured by Shapovalov and Taft (1954) a rough estimate is that these females could have produced just over 3,000 eggs on average or a total of between 60,000 and 510,000 eggs for all ripe females in the run (actual egg production for these reservoir fish may be lower for a given size female than for steelhead). If 10% of these were harvested and fertilized, and assuming fertilization and hatching rates resulting in hatching of 80% of available eggs can be achieved and 40% of hatched eggs can be successfully reared to smolt stage, the 2002 spawning runs in both reservoirs could have been exploited to produce between 2,000 and 16,000 smolts. With the 3% estimated adult return rate developed previously this could have resulted in a run of from 60 to 480 returning first time adult spawners.

This analysis also assumes that ripe males are always captured with ripe females so that eggs can be immediately stripped and fertilized. In fact, review of the daily results of the SFPUC trapping study indicate that this is not always the case (ENTRIX, Inc. 2003) so actual egg production would have been lower.

Although high fertilization, hatching, and survival rates to smolt stage could be achieved, the population size for initiating the run would have been as small as the 2 females from which the eggs were initially taken together with the number of males used to fertilize them. However, there would be some advantage in genetic diversity over natural spawning of the same fish that would be derived from artificially mixing the reproductive products of multiple fish in that each females eggs could be fertilized in equal proportion by all the available males.

3.5 Importation of Smolts from other Hatcheries

If local *O. mykiss* in Alameda Creek watershed reservoirs are not sufficiently abundant to support a supplementation program, another alternative would involve acquiring juveniles produced in an existing hatchery outside the watershed and releasing them in Alameda Creek. There are two existing hatcheries in the Central California Coast steelhead ESU including the Don Clausen Fish Hatchery (Warm Springs Hatchery) on Dry Creek in the Russian River watershed operated by CDFG and a hatchery operated by the Monterey Bay Salmon and Steelhead Project on Big Creek (MBSSP) (Kingfisher Flat Hatchery), a tributary to Scott Creek in Santa Cruz County. There are two drawbacks to this option. First it would introduce fish that are genetically from the same ESU but are not locally adapted. This could negatively impact locally adapted resident *O. mykiss* populations present in Alameda Creek. Additionally, fish produced in hatcheries in other watersheds are likely to have a high tendency to stray, reducing the potential for returns to Alameda Creek.

Don Clausen Hatchery has had few out-of-basin transfers into its broodstock; however, significant numbers of Mad River Hatchery steelhead have been released into the basin and in the early part of the century, steelhead from Scott Creek were released throughout the basin (NMFS 2003). The hatchery has spawned an average of 244 females from 1992 to 2002 and the production goal is 300,000 yearlings released to Dry Creek between December and April (NMFS 2003).

The Kingfisher Flat Hatchery spawns steelhead that return to Big Creek, other parts of the Scott Creek watershed, and from a trap on the San Lorenzo River in Felton. San Lorenzo origin fish are reared separately and released back into the San Lorenzo Basin (NMFS 2003). The MBSSP operation was started in 1976 although hatchery operations at the site date from 1904 to 1942. There are some records of introductions from Mt. Shasta and Prairie Creek hatcheries but since 1976 there have been no out-of-watershed transfers to the population. An average of 98 fish were trapped and 25 females were spawned during the 1990-96 broodyears. All fish are marked before release and hatchery fish are usually excluded from broodstock (NMFS 2003).

The number of out-of-basin smolts needed for a supplementation program is a function of the expected survival rates, return rates, and target run size. Although survival rates may be comparable with those estimated for wild smolts, straying rates are likely to be relatively high and may significantly reduce returns to Alameda Creek. Ideally, the number of returning spawners would fully utilize the available habitat.

A maximum run size for Alameda Creek can be generated from data produced by Shapovalov and Taft (1954) for Waddell Creek. Waddell Creek contains approximately 6 miles of potential spawning and rearing habitat for steelhead and, during the 1930s, supported a spawning run averaging 432 steelhead and 247 coho salmon. Spawning density of salmonids therefore averaged about 600 fish or about 100 fish per mile. Gunther et al. (2000) estimated that removal of barriers in lower Alameda Creek would open up to 4 miles of potential steelhead habitat in Alameda Creek below the Little Yosemite area, 7 miles of potential habitat in Niles Canyon, and up to 9 miles of potential habitat in Arroyo Mocho. If spawning density was similar to Waddell Creek, this habitat could support a steelhead run of up to 2,000 fish. Up to 400 fish could potentially use the highest quality habitat in the reach of Alameda Creek up to Little Yosemite.

These are maximum estimates because the habitat quality in Waddell Creek is closer to optimum for steelhead than in Alameda Creek and production per stream mile is expected to be higher. In addition, survival of smolts is probably higher in Waddell Creek since the stream discharges directly to the ocean with no serious impediments to downstream migration and a relatively short distance between rearing areas and the ocean. There is also the potential for substantial rearing in the lagoon at the mouth of Waddell Creek.

Assuming a 3% smolt-to-spawner return rate, a release of 13,000 smolts would produce sufficient returns to fully utilize habitat in Alameda Creek in the reach downstream of Little Yosemite. If straying rates were as high as 50%, a 26,000 smolt release would be required. A steelhead run, particularly in the initial stages, could likely be viable at lower abundance levels. A returning run of 50 steelhead, for example, could potentially be achieved with a release of 3,000-4,000 out-of-basin smolts.

Summary

The Alameda Creek watershed supports populations of *O. mykiss* with genetic and behavioral characteristics suitable for supplementation of portions of Alameda Creek as they are made accessible to steelhead. Based on preliminary abundance estimates generated in 2002, these populations may not be sufficiently large to initiate large run sizes and supplementation based solely on these populations may not avoid problems associated with small founder populations (Table 2). It is also possible that the abundance of these populations has been underestimated due to inefficiencies in the capture methods and that greater numbers of fish are available for a supplementation program. Additional seasons of trapping and further assessment of gear efficiency and alternative gear types to increase efficiency will be needed to fully evaluate the potential of these populations to support a supplementation program.

The single alternatives most likely to produce the largest initial run sizes would be transplantation of adult spawners or transplantation of juveniles to an artificial rearing facility. These alternatives would produce returns with relatively low potential to stray, however, returning runs produced in both these alternatives are still likely to be quite small and may suffer from reduced genetic diversity.

Artificial spawning, hatching and rearing would be required to achieve significant returns from the available populations in San Antonio and Calaveras Reservoirs, given 2002 levels of abundance. This alternative could result in relatively high genetic diversity if the number of fish spawned was sufficiently high. Straying rates would be expected to be relatively low although releasing production in lower Alameda Creek to avoid emigration losses may increase straying rates.

A combination of smolt transplantation, juvenile artificial rearing, and either adult transplantation, or artificial spawning and rearing would have the best chance of producing the greatest number of returns to Alameda Creek. This would require investment in a rearing facility or egg hatching and rearing facility on Alameda Creek. Smolt and adult transplantation would not require these facilities but probably would need to be combined with use of smolts from outside the Alameda Creek basin to achieve a reasonable number of returning fish.. These actions could be staggered, with adult transplants preceding smolt transplants by two years so that smolts would have a higher probability of all returning in the same year.

Table 2. Comparison of alternatives for supplementing Alameda Creek steelhead run.

Alternative	Number Available in 2002	Assumed "Safe" Removal Rate	Estimated Initial Run Size	Potential Effect on Genetic Diversity	Potential for Straying of Returns	Facilities Required
Smolt Transplant	370	50%?	6 returning adults	Relatively high initial diversity, low due to poor returns	Relatively high, dependant on release location	Trapping Transport
Juvenile Transplant	1700	100%?	<1 returning adult	Relatively high initial diversity, low due to poor returns	Relatively low	Trapping Transport
Juvenile Artificial Rearing	1700	100%?	20 returning adults	Better than smolt or juvenile transplant	Relatively low, dependant on release location	Trapping Transport Grow-out
Adult Transplant	75-330?	10%?	7-33 initial transplants	Potentially high with larger numbers	Low	Trapping Transport
In-Basin Hatchery	20-170 ripe females	10%?	2-17 females + associated males	Potentially high with larger numbers	Relatively low, dependant on release location	Trapping Transport Hatching Grow-out
Out-of-Basin Smolt Transplant	?	N.A.	50-400	Likely swamping of any locally adapted components	High	Transport

It is not immediately clear what permits would be required to conduct any of the supplementation alternatives discussed. The reservoir populations are not included within the ESU since they exist upstream of long-standing natural or man-made barriers. Therefore they are not protected under the ESA and not subject to take restrictions. Alameda Creek, at least upstream of the BART weir, is not presently considered anadromous habitat and, as such, restrictions on planting resident fish in anadromous waters may not presently apply. The MPWMD facility at Sleepy Hollow, which involves ESA protected fish, is covered under a 4(d) limit (exemption from take prohibition) as an artificial propagation program since it involves rescue of stranded fish (Dave Dettman, MPWMD, personal communication, February 2004). It is likely that CDFG would have to approve any facility for hatching and/or rearing fish and such a facility may also need a discharge permit from the Regional Water Quality Control Board.

Preliminary evaluation of supplementation alternatives is based on generalized information from presumed healthy coastal steelhead populations under good environmental conditions. As such, production estimates are assumed to be somewhat optimistic and, while this information is useful for comparing alternatives it does not provide any certainty for predicted results. Actual returns will be influenced by many factors including, conditions in Alameda Creek that depart from those used to develop survival estimates (primarily Waddell Creek); by conditions that depart from average or from "good" environmental conditions; by behavior of reservoir populations of *O. mykiss* that may depart from coastal steelhead, and so on. Greater knowledge of the abundance and population dynamics of reservoir populations will help refine this evaluation.

Literature Cited

ENTRIX, Inc. 2002. Preliminary Report on Alameda Creek Watershed Fish Trapping, 2002. ENTRIX, Inc., Sacramento, California. April 10, 2002.

ENTRIX, Inc. 2003. 2002 Fish Trapping Study Data Summary for San Antonio Creek and Arroyo Hondo. Prepared for: Bureau of Strategic and Systems Planning, Public Utilities Commission, City and County of San Francisco. Prepared by ENTRIX, Inc. Project No. 335808, April 3, 2003.

Gunther, A.J., J. Hagar, and P. Salop. 2000. An Assessment of the Potential for Restoring a Viable Steelhead Trout Population in the Alameda Creek Watershed.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionary significant units. NOAA Technical Memorandum NMFS-NWFSC-42. June 2000.

Monterey Peninsula Water Management District (MPWMD). 1999. 1998-99 Annual Report for the MPWMD Mitigation Program. A report in compliance with the MPWMD Water Allocation Program Final Environmental Impact Report (originally certified in November 1990). Prepared by MPWMD Staff, December 1999.

National Marine Fisheries Service (NMFS). 2003. Co-manager review draft - Preliminary conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead West Coast Salmon. National Marine Fisheries Service Biological Review Team, Northwest Fisheries Science Center and Southwest Fisheries Science Center, Santa Cruz Laboratory. February.

Nielsen, J. 2003. Population Genetic Structure of Alameda Creek Rainbow/Steelhead Trout - 2002. U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska.

Nielsen, J. and Fountain, M. 1999. Microsatellite Analyses of Alameda Creek Rainbow/Steelhead Trout. Alaska Biological Science Center, Anchorage, Alaska.

Shapovalov, L. and Taft, A. C. 1954. The Life Histories of the Steelhead Rainbow Trout and Silver Salmon. Department of Fish and Game, Sacramento, CA. Fish Bulletin No. 98, Fish Bulletin No. 98

Smith, Jerry. 1998. Steelhead and Other Fish Resources of Western Mt. Hamilton Streams. 1998. San Jose State University.