San Francisco Public Utilities Commission
Water Quality Bureau
Sunol, CA

TECHNICAL MEMORANDUM NO. 2-04-006

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Population Size Estimates for Adult Rainbow Trout (*Oncorhynchus mykiss*) in San Antonio and Calaveras Reservoirs

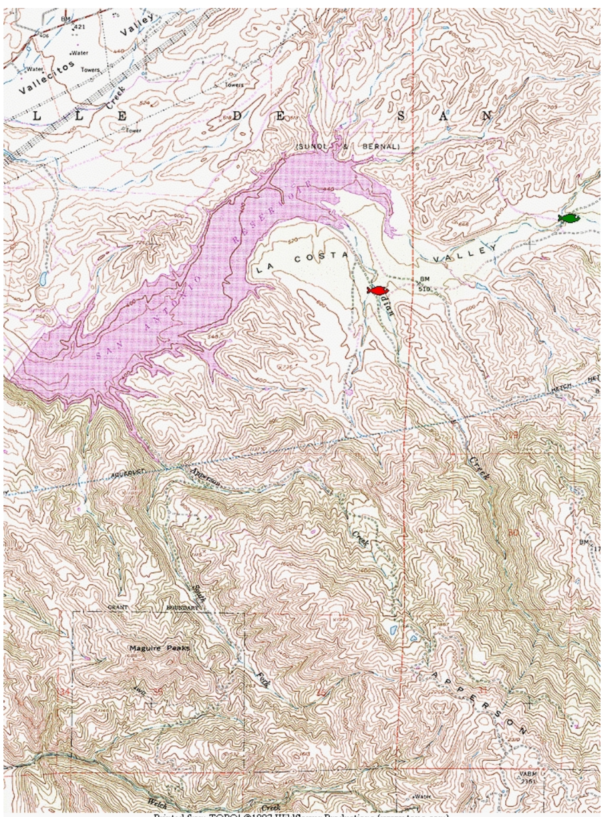

Figure 1. *San Antonio Reservoir and fish trapping stations on San Antonio and Indian creeks.*

San Antonio Reservoir (Figure 1), located in Alameda County, and Calaveras Reservoir (Figure 2), located in Alameda and Santa Clara counties, are owned by the City and County of San Francisco and operated by the San Francisco Public Utilities Commission (SFPUC). Each of the two drinking water storage reservoirs collect local runoff from the Sunol Drainage Unit of the Southern Alameda Creek Watershed. San Antonio Reservoir is also plumbed to accept waters from the SFPUC's Hetch Hetchy Reservoir and the State Water Project. The maximum storage capacity of San Antonio Reservoir is 50,500 acre-feet, while the capacity of Calaveras is 96,850 acre-feet.

When San Antonio and Calaveras reservoirs were constructed on Alameda Creek tributaries, in the mid- and early 1900's, respectively, they effectively blocked the upstream movements of both resident and transient fishes. Reservoir fishes are also not able to move downstream of the two dams during most years, although there is evidence of some downstream movement when the reservoirs spill. Today, there are self-sustaining populations of native cold and warm water fishes, along with non-native warm water species, in both reservoirs and their tributaries (SFPUC *In prep.*).

Over the past several years there has been increased public interest in resident rainbow trout (*Oncorhynchus mykiss*) populations in San Antonio and Calaveras reservoirs. The Alameda Creek Fisheries Restoration Workgroup has proposed using resident rainbow trout from the reservoirs to help jumpstart a steelhead trout run in the ocean-accessible portions of Alameda Creek and its tributaries (Gunther *et al.* 2000). The California Department of Fish and Game has expressed concerns regarding the effects of an extended drawdown of Calaveras Reservoir (to an elevation not greater than 705.5-feet), ordered by the California Department of Water Resources' Division of Safety of Dams in 2001, on resident rainbow trout populations (SFPUC 2004a and 2005). The National Marine Fisheries Service branch of the National Oceanic and Atmospheric Administration has, under the auspices of the Endangered Species Act, proposed to include resident rainbow trout habitat, in part upstream of San Antonio and Calaveras reservoirs, as an element of the Central California Coast Steelhead Evolutionary Significant Unit (NOAA 2005).

Figure 2. *Calaveras Reservoir and fish trapping station on Arroyo Hondo.*

In addition to its mission of managing the Alameda Creek Watershed "to provide the best environment for the production, collection, and storage of the highest quality water for the City and County of San Francisco and suburban customers," the SFPUC has adopted the task of protecting, conserving, enhancing and restoring the area's natural resources (EDAW 2001). Protecting and conserving the resident rainbow trout that are currently in and upstream of San Antonio and Calaveras reservoirs, to both fulfill a portion of the SFPUC's mission and address other issues raised by private and public entities, requires at minimum a basic understanding of their population dynamics, biology and behavior.

Fundamental to understanding rainbow trout in the San Antonio and Calaveras reservoir systems is determining species abundance. The goal of this long-term project is to establish a series of estimates of the number of adult rainbow trout supported by each body of water, quantifying population sizes about once every five years. This Technical Memorandum (No. 2-04-006) represents the SFPUC's initial adult rainbow trout population size estimates.

PROCEDURE

To estimate the population sizes of adult rainbow trout in San Antonio and Calaveras reservoirs, Schnabel's multiple census mark-and-recapture method, as modified by Chapman, was used (Ricker 1975). The formula, $N=\Sigma(C_iM_i)/(R+1)$, where N is the estimated population size, C_i is the total number of fish caught during the i^{th} recapture trip, M_i is the size of the marked fish sub-population (number of initially marked fish, plus new fish marked during previous recapture trips, minus mortalities from previous recapture trips) at the time of the i^{th} recapture trip, and R is the total number of recaptures, is best suited to situations in which too few fish are collected during a single recapture outing to make a reliable population size estimate. It relies on a series of recapture trips in which all fish collected are returned to the population after the non-marked fish are marked. All observed mortalities were recorded and subtracted from the known number of tagged fish prior to population size calculations.

Figure 3. *Rainbow trout were recaptured at San Antonio and Calaveras reservoirs by trolling.*

This study took advantage of the migratory nature of the reservoir's resident adult rainbow trout. During a trapping study from January 9 to June 19, 2003, upstream and downstream moving trout were captured in San Antonio and Indian creeks above San Antonio Reservoir (Figure 1) and in Arroyo Hondo above Calaveras Reservoir (Figure 2). Adult trout were marked with Floy tags (SFPUC 2004b). Fish that were marked on their way upstream were not re-marked if captured again moving downstream. To document tag losses and increase the reliability of marked fish identifications, a portion of each tagged fish's adipose fin was also clipped.

Weekly recapture trips were made beginning August 20, 2003, alternating between the two reservoirs (with the exception of the first week during which both reservoirs were sampled). Downriggers were used to target rainbow trout with a variety of flashers, spoons and plugs trolled in the vicinity of the thermocline. In most cases, SFPUC biologists stayed in an area once a concentration of trout was located. Biologists landed hooked fish on the boat, took length measurements, looked for Floy tags, tag scars or clipped adipose fins, tagged and clipped non-tagged trout, and released fish as quickly as possible. Rainbow trout that died during the process, whether on board the boat or after being released, were kept for training purposes.

FINDINGS

San Antonio Reservoir – Fifty-seven and 103 adult rainbow trout were tagged and fin clipped in San Antonio and Indian creeks, respectively, during the 2003 fish trapping study, for a total of 160 marked fish (SFPUC 2004b). There were no documented mortalities of tagged trout during the trapping study. One tagged adult trout was, however, observed in a relatively small upstream pool in Indian Creek after connectivity between the stream and the reservoir was lost (Brian Sak, personal communication). A single tagged fish mortality was also observed in the reservoir, near the dam, during the recapture portion of the study (Frank Marino, personal communication). Consequently, reservoir population estimate calculations were based on an initial marked sub-population of 158 rainbow trout.

There were six recapture trips made to San Antonio Reservoir between August 20 and October 22, 2003, during which a total of 49 adult rainbow trout were collected (Table 1). Fifteen of the fish captured were previously tagged, while partially clipped adipose fins identified two trout that had lost their Floy tags. A single tagged rainbow trout was recaptured two times. There were three adult trout mortalities during the recapture portion of the study, with the condition of all other released fish being reported as "good."

Table 1. *Rainbow trout reservoir recapture trip summary.*

San Antonio Reservoir

Sampling Date	Number of Fish: Total Captured	Tagged	Adipose Clip	Total Marked	Mortalities
20-Aug-03	0	- -	- -	- -	- -
28-Aug-03	7	1	1	2	0
11-Sep-03	17	4	0	4	2
25-Sep-03	5	4	0	4	1
09-Oct-03	13	3	1	4	0
22-Oct-03	7	3	0	3	0
Totals	49	15	2	17	3

Calaveras Reservoir

Sampling Date	Number of Fish: Total Captured	Tagged	Adipose Clip	Total Marked	Mortalities
22-Aug-03	2	0	1	1	1
05-Sep-03	0	- -	- -	- -	- -
18-Sep-03	2	0	0	0	0
01-Oct-03	1	1	0	1	0
16-Oct-03	2	0	0	0	0
30-Oct-03	0	- -	- -	- -	- -
Totals	7	1	1	2	1

Based on the Chapman modified Schnabel formula, it is estimated that San Antonio Reservoir had a population of 460 adult rainbow trout ($P^1(294 \leq N \leq 760)=0.95$) in 2003. Because the expression $MC>4N$ is true, the estimate can be considered acceptable.

Calaveras Reservoir – A total of 129 adult rainbow trout were tagged and clipped in Arroyo Hondo during the SFPUC's 2003 fish trapping study (SFPUC 2004b), with no

[1] 95 percent confidence intervals are based on a binomial distribution with R as the Poisson variable.

documented mortalities. There were no tagged adult rainbow trout observed in pools in Arroyo Hondo during summer snorkel surveys (SFPUC *In prep.*) and there were no reports of dead fish in the reservoir prior to the recapture portion of the study. Consequently, reservoir population estimate calculations were based on an initial marked sub-population of 129 rainbow trout.

Six recapture trips were made to Calaveras Reservoir, between August 22 and October 30, 2003, during which a total of seven rainbow trout were collected (Table 1). Only one of the seven fish collected was tagged, while one previously tagged trout was identified by its partially clipped adipose fin. With the exception of a single mortality, all fish recaptured were released in good condition.

The Chapman modified Schnabel formula estimated that Calaveras Reservoir had a population of 304 adult rainbow trout (P[2]($111 \leq N \leq 759$)=0.95) in 2003. The estimate should be considered negatively biased (underestimate), however, because MC>4N is false.

DISCUSSION

A mark-and-recapture study estimates the size of a population at the time that individual members of that population are marked, regardless of the amount of time between marking and subsequent recapture attempts (Everhart and Youngs 1981). The time lag between marking and recapture, however, combined with the ability of fishes to move around, requires that a set of assumptions be met when estimating population sizes using this method. Although mark-and-recapture estimates are not as accurate as direct counts, they can be used with confidence when the following assumptions are adequately addressed:

Assumption 1: Marked fish are identifiable. The rainbow trout in this study were double marked to minimize the possibility of missing marked fish. Floy tags, which were inserted in the back of captured trout next to their dorsal fin, are readily observable, but are sometimes shed after several days when not inserted properly. As an additional measure, the adipose fins of tagged trout were partially clipped. Adipose fin clipping of adult trout can also be problematic, however, because the fins tend to grow back over time. Although SFPUC biologists observed partial re-growth of adipose fins in tag recaptures, they were confident in their ability to identify adult rainbow trout that had lost their Floy tags.

Assumption 2: The marking method and marks do not affect marked fish. There exists the potential for affecting the health and/or behavior of a relatively sensitive species, like rainbow trout, when capturing, handling and physically manipulating them. In extreme cases, where there is delayed mortality, a population size can be over-estimated because the number of fish in the marked sub-population is actually lower than that used in the calculations. The same outcome is possible when marked individuals are more susceptible to predation than unmarked fish. Every effort was made to reduce delayed mortality by handling trout as little and as gently as possible during both the SFPUC's trapping program and the recapture sampling. Floy tagging, when performed correctly, is relatively benign. This study also used low-visibility green tags to ensure that tagged trout were no more obvious to predators than untagged fish. Adipose fin clipping has been shown to have little, if any, affect on trout health or behavior. Biologists noted dead fish during both phases of the project, and other

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[2] 95 percent confidence intervals are based on a binomial distribution with R as the Poisson variable.

than the single marked trout found floating near the dam at San Antonio, there was no evidence of delayed mortality.

Assumption 3: The sampling is random. Marked and unmarked fish must be equally susceptible to being collected during the recapture phase of the sampling. Because both reservoirs are closed systems, with no inflow or outflow during the time of year when recapture trips were conducted, emigration was not a concern. The stratification of San Antonio and Calaveras reservoirs (when waters below the thermocline have too little oxygen to support fish and waters above the thermocline are warmer than what trout typically use) concentrated the marked and unmarked adult rainbow trout at the same general depths, such that nonrandom vertical distributions of fish were not a concern. There was no evidence to support or refute the idea that tagged rainbow trout are more or less likely to be captured using trolling gear than untagged trout.

Assumption 4: There are no additions to the population during the project. The connection between San Antonio Reservoir and its tributaries consistently goes dry shortly after the end of the wet-weather season, and was the case in 2003. Consequently, any rainbow trout remaining in the streams following the conclusion of the fish trapping study (trapping ends when flows at the trapping site are too low to capture fishes) could not enter the reservoir population prior to the winter following the conclusion of the recapture phase of this project. The Arroyo Hondo, on the other hand, typically flows into Calaveras Reservoir throughout the year, and additional adults may have entered the reservoir population after the recapture phase of this study began. However, the low numbers of adult trout observed in Arroyo Hondo during summer snorkel and autumn electrofishing surveys, combined with relatively low stream flows, make these downstream movements of adults after spring unlikely. SFPUC waters are closed to the general public, and population increases due to the stocking of adult rainbow trout for anglers is not a concern. An issue that does need further investigation, however, is the potential for sub-adults residing in the reservoir, that are too small to be considered part of the adult population at the time of the initial marking, growing large enough during the project to be deemed adults by the end of the recapture phase.

With minor exceptions, the generally satisfied assumptions inherent to mark-and-recapture studies suggest that the population size estimates generated for adult rainbow trout in San Antonio and Calaveras reservoirs are reliable. The estimate at San Antonio can also be considered unbiased due to a relatively large sample size (the number of trout marked multiplied by the total number of fish captured is greater than four times the population estimate). At Calaveras, however, the relatively small number of rainbow trout caught during the recapture phase of the project likely leads to an underestimate of the true population size.

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