THE DISTRIBUTION AND ABUNDANCE OF STEELHEAD IN TRIBUTARIES TO MORRO BAY, CALIFORNIA

Introduction

The Coastal San Luis Resource Conservation District (CSLRCD), in association with other resource management agencies, is initiating a steelhead habitat restoration plan in the watershed of Morro Bay, California. Another project of the CSLRCD is to coordinate permitting procedures that will allow local landowners to conduct instream and riparian restoration projects within several tributaries known to support spawning and rearing habitat for steelhead (*Oncorhynchus mykiss*). As part of the coordinated permitting program, the National Marine Fisheries Service (NMFS) has requested the CSLRCD to collect information on the distribution and abundance of juvenile steelhead in those tributaries that are expected to receive restoration efforts. Currently, steelhead inhabiting the Morro Bay watershed are federally listed as a "threatened" stock in the South-Central California Coast Evolutionarily Significant Unit.

This report describes the methods and results of surveys conducted by Thomas R. Payne and Associates (TRPA) to describe the distribution and abundance of juvenile steelhead in Morro Bay's two principal tributaries: Chorro Creek and Los Osos Creek. Cursory surveys were also conducted in Dairy Creek and Pennington Creek (tributaries to Chorro Creek), and in Warden Creek (tributary to Los Osos Creek). Many of the specifics of this study plan were determined following conversations with Anthony Spina of NMFS, Malcolm McEwen of CSLRCD, Bob Neale of Sustainable Conservation, and Mark Allen of TRPA. This study was funded by the CSLRCD with assistance from the California Department of Fish and Game (CDFG), the State Water Resources Control Board, and the Morro Bay National Estuary Program.

Purpose

The primary purpose of the fish abundance survey was to describe the relative distribution and abundance of juvenile steelhead (and occurrence of other species) throughout the accessible rearing habitat in Chorro Creek and Los Osos Creek. Overall estimates of abundance were made for the number of juvenile steelhead that inhabit pool habitats of each stream during October 2001 using direct observation (snorkeling) under the Method of Bounded Counts (MBC) protocols as recently developed by Dr. David G. Hankin of Humboldt State University and Dr. Michael Mohr of NMFS (Hankin and Mohr, unpublished manuscript). Because the estimates were conducted during a single time frame, and because riffles and other habitat areas (including large lengths of private lands) were not sampled, the resulting estimates should be considered as a "snapshot" picture of steelhead abundance in the Morro Bay watershed in the fall of 2001. These results should not be assumed to accurately represent steelhead distribution and abundance during other seasons, years, or in other tributaries.

Study Areas

The abundance surveys focused on two study areas, Chorro Creek and Los Osos Creek. Chorro Creek is accessible to upstream migrant steelhead from its mouth to Chorro Reservoir, a distance of approximately 12.6 miles (Figure 1). The Chorro Creek sampling area began at the upstream end of the lagoon/marsh habitat at approximate river mile (RM) 1.6, and extended to the mouth of San Bernardo Creek at RM 2.65. For the next 3.1 miles, Chorro Creek flowed through private land where access was not permitted during the 2001 habitat mapping survey. The remaining 6.8 miles of stream was available for fish sampling, except for a short (approximately ½ mile) stretch of dry channel near the California Mens Colony.

Los Osos Creek extends approximately 10.3 miles from Morro Bay to its headwaters (Figure 2). In the lower four miles Los Osos Creek flows at a very low gradient through a wide valley (Los Osos Valley). Portions of the lower creek near Baywood Park were inspected by CSLRCD personnel in the late summer of 2001 and were found to be dry (Malcolm McEwen, personal communication). Stream gradient increases

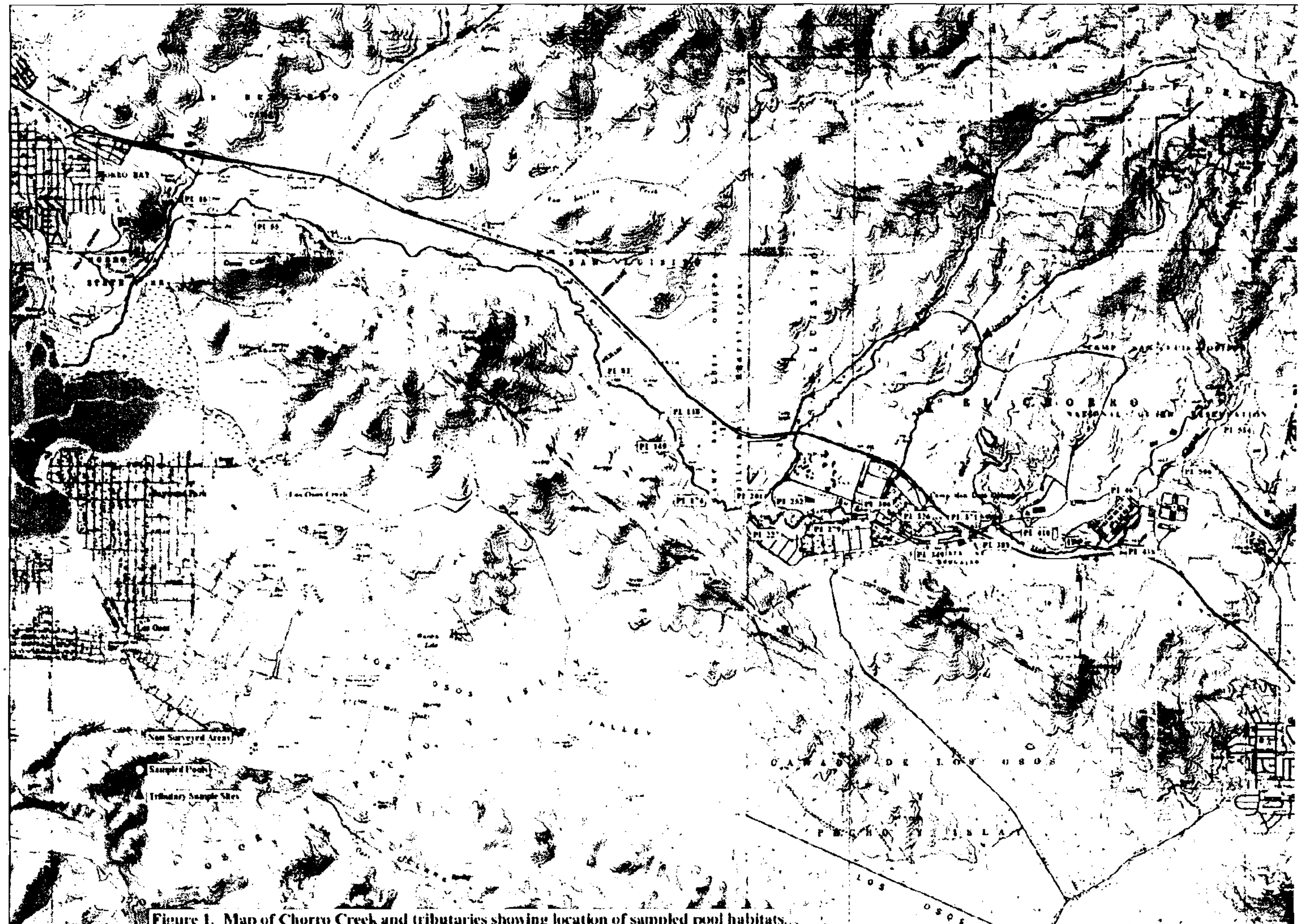


Figure 1. Map of Chorro Creek and tributaries showing location of sampled pool habitats.

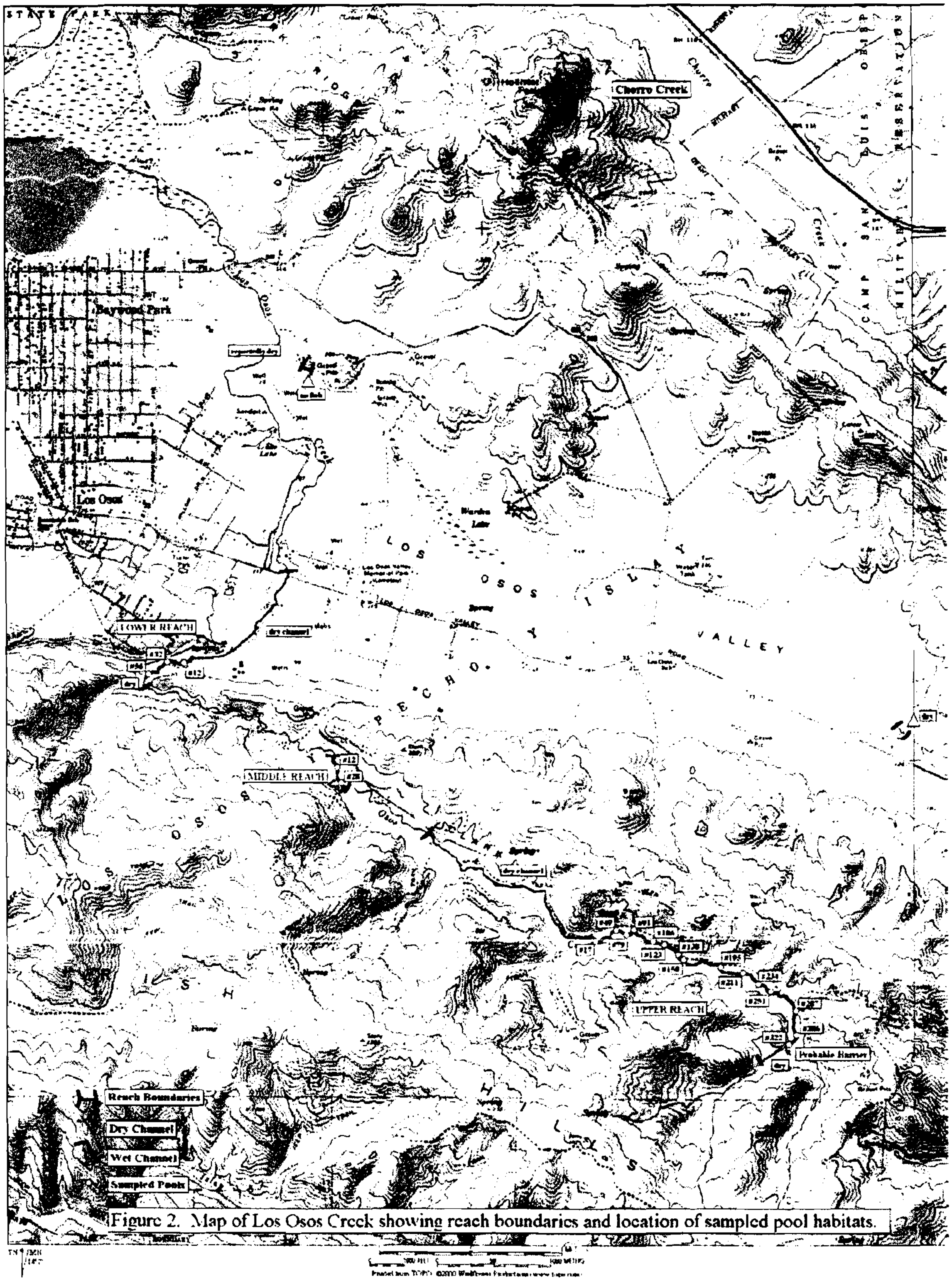


Figure 2. Map of Los Osos Creek showing reach boundaries and location of sampled pool habitats.

as Los Osos Creek passes through and between high (500-1,000 ft) ridges into Clark Valley for the next five miles. In its final mile Los Osos Creek leaves Clark Valley and climbs steeply to its headwaters. Three sections of Los Osos Creek were available for sampling (i.e., with access permission) in October 2001. The Lower Reach consisted of approximately 1,630 feet of wetted channel in Los Osos Valley just prior to entering Clark Valley. Los Osos Creek was dry both below the lower reach (for approximately 4,000 feet down to the Los Osos Valley Road bridge) as well as immediately above the Lower Reach (for 500 feet to the end of access). The Middle Reach was located in Clark Valley with approximately 968 feet of wetted stream available for sampling. Surface flow existed both above and below this reach. The Upper Reach was approximately 3.1 miles in length and was located at the upper end of Clark Valley. The lower 6,300 feet and the upper-most 1,000 feet of the Upper Reach was largely dry with scattered intermittent pools, consequently 9,095 feet of wetted channel was available for sampling. The upper intermittent channel began immediately above an eight foot bedrock drop that was judged to be a migrational barrier at all flows (Figure 3). A bankside inspection of the inter-mittent pools above this barrier revealed the apparent absence of fish.

Figure 3. Upstream barrier on Los Osos Creek.

Limited and qualitative fish sampling was also conducted in the Chorro Creek tributaries Pennington Creek and Dairy Creek, and in Warden Creek (sometimes known as the North Fork of Los Osos Creek) in the Los Osos watershed. Three sites with a total of 10 pools were sampled in both Pennington Creek and in Dairy Creek (Figure 1). The lower sites for Dairy and Pennington creeks were located downstream of Highway 1 and the uppermost sites were located at the furthest upstream access, with a middle site located at a convenient point in between. Approximately 100 feet of lower Warden Creek was also sampled, with a brief inspection of upper Warden Creek near the 100 foot msl elevation (Figure 2). San Bernardo Creek and San Luisito Creek may also be important spawning tributaries to Chorro Creek, however access was not obtained to survey those streams.

Sampling Methodologies

Because of the threatened status of SCCC steelhead, state and federal agencies prefer passive fish sampling methods such as direct observation (i.e. snorkeling). Snorkeling not only minimizes disturbance to threatened steelhead; it has the additional advantage of being rapid in assessment. This factor can allow an increase in sample sites for a given cost with an overall improvement in population estimates and variances over the slower and more costly electrofishing methodologies (Hankin and Reeves 1988). Although snorkeling alone has typically been viewed as providing only an "index" of abundance that represents an unknown fraction of the true population (TRPA 1999), the recently developed MBC protocols has been successfully used to develop reliable estimates of true abundance of coho salmon (*O. kisutch*) in Northern California streams (Dave Hankin, personal communication). The applicability of the MBC for steelhead, which are more cryptic and elusive than coho, in the silty streams of Central and Southern California, has not been fully investigated. However, TRPA has recently conducted MBC surveys in a nearby stream (San Luis Obispo Creek) with the approval of Anthony Spina of NMFS.

Dive counts were conducted in 20 pool habitats in Chorro Creek and 20 pool habitats in Los Osos Creek. Repeat dive counts according to MBC protocols were conducted in four pools in each stream. Because minimal streamflows in Los Osos Creek and in Chorro Creek prevented using direct observation methodologies in run and riffle habitats (which are shallower than pool habitats), sampling effort (and subsequent estimates of abundance) was limited to pool habitats.

Habitat Type Stratification

Chorro Creek. Chorro Creek was habitat mapped by the CSLRCD during the summer of 2001, using the protocols recommended by the California Department of Fish and Game (Flosi et al.1998). According to that method, each distinct habitat unit was assigned to one of 24 possible habitat types, which can then be regrouped into three categories: riffles, flatwater, and pools. This survey conducted fish surveys only within pool habitats (all 15 pool types considered). The remaining nine habitat types were not sampled because the small size of the streams and the shallow nature of those habitat types prevented accurate estimation of fish abundance by direct observation methodologies. Pools found within split channels were also excluded from selection due to the small size and shallow nature of those units. Based on the above criteria, 215 pool habitat units were available for sampling in Chorro Creek.

Los Osos Creek. Recent habitat mapping data was not available for Los Osos Creek; therefore TRPA mapped pool habitats in the accessible areas of Los Osos Creek prior to habitat unit selection. Los Osos Creek habitat units were mapped using a pool, riffle, and run classification method similar to the three categories described in Flosi et al. (1998). The lengths, widths, and depths of all pool habitats were recorded along with unit location (using hipchain and GPS receivers). All pool habitats deemed unacceptable for diving due to insufficient depth, excessive instream cover, tainted water quality, or other significant factors, were noted and excluded from selection. Photographs and water temperatures were periodically taken, and surveyor flagging periodically placed to assist with the relocation of selected habitat units. As stated above, very low flows in Los Osos Creek prohibited effective sampling in run or riffle habitats using direct observation methodologies. The total number of pool habitats thus available for sampling the Lower, Middle, and Upper Reaches of Los Osos Creek were 14 pools, 11 pools, and 82 pools, respectively (Appendix A).

Habitat Unit Selection

Twenty pools were selected in each stream by systematic sampling. Systematic sampling is a computationally and logistically simple procedure that is efficient for populations that exhibit linear or random trends, but may be inefficient if the population exhibits regular, periodic trends (Jessen 1978). Although data on longitudinal fish densities were not available for Chorro Creek, the distribution of four major tributaries (San Bernardo Creek at river mile 2.7, San Luisito Creek at 3.8 mi., Pennington Creek at 7.7 mi., and Dairy Creek at 9.1 mi.) and a significant stretch of dry channel in upper Chorro Creek was expected to produce a longitudinal trend in fish densities. Likewise, Los Osos Creek changes from a low gradient, northerly flowing stream in a wide valley (Los Osos Valley), to a steeper, westerly flowing stream in a much narrower valley (Clark Valley). The low sample size of 20 pools per stream effectively prevented the construction of multiple reach strata to account for such possible trends in fish densities, hence systematic sampling was used to ensure that sample sites were distributed along the full length of the study streams. The pools were selected using a circular systematic approach with a random start. Circular systematic sampling ensures that each unit has an equal probability of being selected and that the resulting mean is an unbiased (due to sampling design) estimate of the population mean (Murthy 1977). These conditions are not met with standard, or linear systematic sampling procedures.

In Chorro Creek, an initial systematic sample of only 10 pools was selected because TRPA was requested to sample 10 run habitats in addition to the 10 pools (Anthony Spina, NMFS, personal communication). After on-site inspection revealed that run habitats in Chorro Creek were infeasible for diving, a second systematic sample of 10 pools was drawn. Although two independent systematic samples of 10 pools each were thus selected, the 20 pools were subsequently treated as a single sample when calculating estimates of abundance. In Los Osos Creek, a single systematic sample of 20 pools was selected after combining the mapping from the three reaches. Thus, the number of pools selected from each reach was approximately proportional to the amount of pool habitat in each reach (i.e., the shortest reach had the fewest sampled pools, the longest reach had the most sampled pools).

Four of the twenty pools in each stream were randomly selected for repeat sampling according to the MBC protocols. Divers did not know which units were selected for bounded counts until after the first count was completed. In Chorro Creek, four additional pools were selected for calibration (for a total of eight pools) because none of the initial four pools contained steelhead, and the MBC cannot calculate estimates when no fish are observed in the calibration units. In order to ensure that the additional calibration pools contained fish, the four new pools were selected from among the pools known to contain steelhead (i.e., based on the initial survey of the 20 pools). This purposive selection of pools known to contain fish is a departure from the MBC protocol, but was recommended by the protocol developer (Dave Hankin, personal communication).

Dive Counts

One or two divers (depending on unit width and water visibility) conducted fish counts in all selected pool habitats. Divers cautiously enter the lower end of each habitat unit and proceed together upstream to the unit head. Each diver enumerated the number of steelhead observed in his/her side of the stream channel; the divers counts from the single pass were then added to estimate an index of fish abundance within the habitat unit. Two size classes were used for steelhead/rainbow trout: young-of-year (0+) fish <10cm in length, and juvenile/adult (1+ and older) fish ≥10cm in length. The lengths used to designate the size classes was based on trapping and dive count data collected in San Luis Obispo Creek by TRPA during 2000 and 2001. Data were recorded onto underwater slates during the dive counts, then transferred to data sheets after each dive. The presence of other species of fish or other large aquatic organisms was also noted for each dive unit. In Chorro Creek, the abundance of Sacramento pikeminnow (*Ptychocheilus grandis*) less than or greater than 10cm was estimated, rather than enumerated, due to the very high numbers seen in many of the pools.

The single-pass dive counts were calibrated to estimate the "true" abundance of fish by the MBC in a subsample of pool habitats. Following the initial dive count, the divers removed a hidden label that indicated whether or not the unit was selected for bounded counts. If not, the divers continued on to the next selected habitat unit. If selected for bounded counts, the divers waited an appropriate amount of time (10 to 20 minutes) for the water visibility in the dive unit to return to normal. After that time period, the divers conducted a second dive count in an identical manner as the first count. This procedure was repeated until a total of four dive counts were collected at the MBC unit.

After diving each selected habitat unit, the following information was collected: starting and ending dive times, water temperature, and estimated water visibility. Most sampled habitat units were photographed (Appendix B), and pool dimensions in Chorro Creek (length, mean width, and mean depth) were re-measured.

Quality Assurance / Quality Control (QA/QC)

Several QA/QC procedures were followed to ensure that all data was collected, transcribed, and analyzed accurately. The specific habitat units selected for sampling were relocated and verified using a combination of prominent landmarks (as identified in the habitat mapping data), habitat mapping flags (previously placed), hipchain measurements, and GPS information. Dive counts were conducted by fisheries biologists who had just completed one or more full seasons of direct observation experience. Discussing each divers lane assignment and visual orientation prior to the dive maximized the accuracy of dive counts. Also, divers communicated verbally whenever a fish was observed to pass downstream along a lane boundary to prevent double counting or other recording errors. Divers calibrated their estimations of fish size category (≤10cm or >10cm) by reference to a ruler attached to a wrist slate. Data was transferred from dive slates to pre-formatted data sheets to ensure the completeness of data collection. All spoken data was repeated by the data recorder to ensure correct transcription. Finally, the MBC was employed in 12 habitat units that received four replicate counts each, which helped to evaluate the variability and repeatability of dive counts. In the office, all data analysis was conducted from computer files verified for accurate transcription.

Estimation of Fish Abundance

The following equations used to estimate fish abundance in each study area are from David G. Hankin and Michael Mohr's 2001 versions of "Improved two-phase survey designs for estimation of fish abundance in small streams" (unpublished manuscript).

MBC Estimate

For the habitat units receiving repeat dive counts in each stream, the estimation of "true" abundance in those habitats was calculated by the MBC as:

$\tilde{y}_B = D_{[m]} + (D_{[m]} - D_{[m-1]})$ where $\tilde{y}_B$ is the bounded count estimate of true abundance,

$D_{[m]}$ is the largest of the four dive counts, and $D_{[m-1]}$ is the second largest of the four dive counts.

Estimated Abundance of Steelhead Per Study Stream

To estimate the abundance of juvenile steelhead (by size class or both size classes combined) in all available pool habitats (excluding other habitat types and non-accessible areas) in either of the study streams, we will use the following definitions:

Definitions	Variable
total number of available dive units (pools)	**N**
number of dive units sampled	**n_1**
number of calibrated dive units	**n_2**
mean diver counts in sampled dive units	**$x_{1\ bar}$**
mean diver counts in calibrated dive units	**$x_{2\ bar}$**
mean "true" abundance in calibrated dive units	**$y_{2\ bar}$**
ratio of true abundance to 1st pass counts in calibrated dive units	**B_x**

None of the auxiliary variables (unit length, surface area, or volume) were used in the estimator due to their poor correlation with dive counts.

The estimated abundance of juvenile steelhead ($\hat{t}_{y,D}$) is calculated as:

$$\hat{t}_{y,D} = N\bar{y}_2[\frac{\bar{x}_1}{\bar{x}_2}]$$ with a variance of:

$$\hat{V}(\hat{t}_{y,D}) = N^2(1-\frac{n_1}{N})\frac{s_e^2(\bar{y}_2)}{n_1} + N^2(1-\frac{n_2}{n_1})(\frac{\bar{x}_1}{\bar{x}_2})^2\frac{s_e^2(\bar{y}_{2,x})}{n_2}$$ where

$$s_e^2(\bar{y}_2) = \sum_{k=1}^{n_2}(y_k - \bar{y}_2)^2/(n_2-1)$$ and

$$s_e^2(\bar{y}_{2,x}) = \sum_{k=1}^{n_2}(y_k - \hat{B}_x x_k)^2/(n_2-1)$$ with $$\hat{B}_x = \bar{y}_2/\bar{x}_2$$

An important component of the new MBC methodology is the estimation and correction of the negative bias that is associated with dive counts. To estimate bias, the diver observation probability is first required:

Definitions	Variable
diver observation probability in unit k	p_k
the i[th] diver count in unit k	D_{ik}
number of repeat counts (=4)	m_D
overall diver observation probability	p
number of calibration pools where D_k bar is >0	n_2*

$$\hat{p}_k = 1 - \frac{s_k^2(D)}{\overline{D}_k} \quad \text{where } \overline{D}_k = \sum_{i=1}^{m_D} D_{ik} / m_D \quad \text{and } s_k^2(D) = \sum_{i=1}^{m_D} (D_{ik} - \overline{D}_k)^2 / (m_D - 1)$$

$$\hat{p} = \frac{1}{n_2^*} \sum_{k=1}^{n_2^*} \hat{p}_k$$

Bias is then calculated using:

Definitions	Variable
original bounded count estimate	$\tilde{y}_B$
bias-corrected bounded count estimate	$\tilde{y}_B$ *
number of repeat counts	m

$$\tilde{y}_B{*} = \tilde{y}_B - \sum_{u=0}^{\tilde{y}_B - 1} \hat{F}(u)^{m-1}(m - (m+1)\hat{F}(u)) \quad \text{where} \quad \hat{F}(u) = \sum_{j=0}^{u} \binom{\tilde{y}_B}{j} \hat{p}^j (1-\hat{p})^{\tilde{y}_B - j}$$

The bias-corrected dive count estimate, or $\tilde{y}_B$ *, is then inserted back into the equations for $\hat{t}_{y,D}$ and its variance to produce a bias-corrected estimate of abundance and variance for each stream.

95% confidence intervals for the stream abundance estimates were calculated as: $\hat{t}_{y,D} \pm t_{n-1}\sqrt{\hat{V}(\hat{t}_{y,D})}$

Results

Pool habitat and fish count data for Chorro, Los Osos, Pennington and Dairy creeks are listed in Table 1. The average temperature in Chorro Creek was 61.3° F and the average visibility was 7.6 feet, while the temperature of Los Osos Creek was 58.0° F with a visibility of 9.4 feet. Dairy and Pennington creeks had mean temperatures of 60.3°F and 58.0°F with visibiltities of 7.6 feet and 10.0 feet respectively.

Chorro Creek

Steelhead were relatively rare in Chorro Creek pool habitats. The number of steelhead per pool ranged from zero fish (in 14 pools) to 7 fish and averaged 0.8 fish/pool. The estimated abundance of juvenile steelhead in all available pools in Chorro Creek was 221 fish with a 95% confidence range of 16 – 437 fish (lower range equals the actual number of fish observed; Table 2). The wide confidence range may be due in part to the purposive selection of four calibration pools that contained fish, which resulted in an average fish

Table 1. Pool habitat and fish count data for Chorro, Los Osos, Pennington, and Dairy Creeks, Morro Bay Watershed, California, 25-30 October 2001. All unlabeled units feet. Pool numbers, distances upstream (from creek mouths), and GPS coordinates for Chorro, Pennington, and Dairy are from CSLRCD habitat mapping data. All habit for Los Osos Creek (pool numbers and distances are from bottom of reaches) are from TRPA mapping data (Appendix A). Species abbreviations are: SPD=speckled dac STB=stickleback, SKR=sucker, SCP=sculpin.

		Pool	Distance	GPS Coordinates		Mean	Mean	Surface	Volume	Water		Dive	# STEELHEAD <10cm				# STEELHEAD 10cm+				# All STEELHEAD				# PIKEMINNOW	
Creek	Reach	No.	Upstream	N35°x'x" / W120°x'x"	Length	Width	Depth	Area (ft²)	(ft³)	Temp(°F)	Visibility	Time	Dive1	Dive2	Dive3	Dive4	Dive1	Dive2	Dive3	Dive4	Dive1	Dive2	Dive3	Dive4	<10cm	10cm+
Chorro		16	9,367	21'28"/49'32"	26	12.7	0.55	330	182	56	6.5	902	0	-	-	-	0	-	-	-	0	-	-	-	80	0
Chorro		55	13,253		77	16.9	1.56	1,301	2,030	57	7.0	825	0	0	0	0	7	6	4	4	7	6	4	4	2,000	20
Chorro		83	31,544	20'22"/46'10"	77	18.6	1.10	1,432	1,575	61	6.5	1114	0	-	-	-	0	-	-	-	0	-	-	-	1,000	20
Chorro		118	34,469		32	13.7	0.88	438	386	62	5.5	945	0	0	0	0	2	1	2	1	2	1	2	1	60	20
Chorro		146	35,917	19'55"/45'35"	32	8.2	0.48	262	125	64	8.5	1233	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Chorro		174	38,664		136	12.8	0.95	1,741	1,654	66	8.0	1430	0	-	-	-	0	-	-	-	0	-	-	-	1,000	40
Chorro		201	40,709	19'31"/45'08"	88	12.7	1.29	1,118	1,442	61	9.0	1101	0	0	0	0	1	1	1	1	1	1	1	1	50	50
Chorro		227	42,209		87	10.3	1.24	896	1,111	60	12.0	1541	0	-	-	-	0	-	-	-	0	-	-	-	230	20
Chorro		252	43,736	19'27"44'45"	75	15.3	1.89	1,148	2,169	60	8.0	1613	0	-	-	-	0	-	-	-	0	-	-	-	265	35
Chorro		279	46,116		97	13.0	0.83	1,261	1,047	60	7.0	846	0	-	-	-	0	-	-	-	0	-	-	-	130	40
Chorro		306	48,241	19'27"/44'04"	37	10.3	1.54	381	587	61	10.0	1203	0	0	0	0	4	2	5	2	4	2	5	2	80	20
Chorro		326	49,452		54	16.8	0.88	907	798	61	7.0	945	0	0	0	0	0	0	0	0	0	0	0	0	22	0
Chorro		349	51,103	19'17"/43'34"	26	9.2	0.75	239	179	61	9.0	1111	0	-	-	-	0	-	-	-	0	-	-	-	5	0
Chorro		371	52,439		14	8.7	0.73	122	89	61	8.0	1126	0	-	-	-	1	-	-	-	1	-	-	-	0	0
Chorro		388	53,613	19'22"/43'07"	69	13.0	0.89	897	798	62	8.0	1143	0	-	-	-	0	-	-	-	0	-	-	-	10	0
Chorro		410	55,240		99	9.8	1.35	970	1,310	60	4.0	1251	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorro		438	59,165	19'14"/42'07"	38	9.0	0.58	342	198	62	8.0	1424	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorro		467	61,565		78	11.0	0.63	858	541	63	8.5	1518	0	-	-	-	0	-	-	-	0	-	-	-	4	0
Chorro		506	63,961	19'50"/41'37"	85	13.0	1.20	1,105	1,326	62	7.5	1221	0	-	-	-	1	-	-	-	1	-	-	-	150	30
Chorro		534	65,952		35	19.5	1.02	683	696	65	3.0	1253	0	-	-	-	0	-	-	-	0	-	-	-	8	0
Los Osos	Lower	12	312		23	6.8	0.42	156	66	58	8.5	1153	2	2	0	0	0	0	0	0	2	2	0	0	0	0
Los Osos	Lower	32	818		24	5.5	0.63	132	83	58	7.5	1314	0	-	-	-	0	-	-	-	0	-	-	-	0	0
Los Osos	Lower	56	1,619	17"59.0"/49'28.1"	20	8.3	0.76	166	126	58	10.5	1328	51	-	-	-	1	-	-	-	52	-	-	-	0	0
Los Osos	Middle	12	294	*(coord. @ tributary)*	34	7.3	0.54	248	134	60	11.5	1422	9	10	11	14	5	6	4	6	14	16	15	20	0	0
Los Osos	Middle	28	762		21	6.3	0.63	132	83	60	9.5	1544	14	-	-	-	0	-	-	-	14	-	-	-	0	0
Los Osos	Upper	17	336	16'37.2"/46'54.5"	40	5.4	0.62	216	134	60	9.0	1631	28	-	-	-	0	-	-	-	28	-	-	-	0	0
Los Osos	Upper	49	1,009	16'41.6"/46'46.8"	19	3.4	0.49	65	32	59	9.0	1648	3	-	-	-	0	-	-	-	3	-	-	-	0	0
Los Osos	Upper	79	1,502		24	4.4	0.74	106	78	56	11.5	915	18	-	-	-	0	-	-	-	18	-	-	-	0	0
Los Osos	Upper	91	1,731	16'42.5"/46'42.0"	30	5.9	0.61	177	108	57	11.5	934	3	-	-	-	0	-	-	-	3	-	-	-	0	0
Los Osos	Upper	106	2,380		27	5.2	0.46	140	65	57	11.5	954	9	-	-	-	2	-	-	-	11	-	-	-	0	0
Los Osos	Upper	123	2,811	16'38.2"/46'31.3"	16	6.2	0.98	99	97	59	9.0	1016	12	-	-	-	0	-	-	-	12	-	-	-	0	0
Los Osos	Upper	138	3,245		20	5.7	0.63	114	72	59	8.5	1044	6	4	8	6	0	0	0	0	6	4	8	6	0	0
Los Osos	Upper	150	3,448		21	4.5	0.87	95	82	59	6.0	1155	12	-	-	-	1	-	-	-	13	-	-	-	0	0
Los Osos	Upper	195	4,829	16'31.9"/46'11.4"	10	5.5	0.41	55	22	59	8.0	1233	9	-	-	-	2	-	-	-	11	-	-	-	0	0
Los Osos	Upper	211	5,429		24	5.0	0.41	120	49	57	-	1300	6	-	-	-	0	-	-	-	6	-	-	-	0	0
Los Osos	· Upper	234	6,044		20	8.2	0.93	164	153	58	10.5	1322	12	-	-	-	1	-	-	-	13	-	-	-	0	0
Los Osos	Upper	251	6,513		20	5.0	0.54	100	54	58	10.5	1345	7	6	8	8	0	0	0	0	7	6	8	8	0	0
Los Osos	Upper	287	7,608		10	5.5	0.54	55	30	57		-	7	-	-	-	1	-	-	-	8	-	-	-	0	0
Los Osos	Upper	306	8,294		36	8.3	0.68	299	203	59	8.0	1519	14	-	-	-	0	-	-	-	14	-	-	-	0	0
Los Osos	Upper	322	8,716		26	5.7	0.71	148	105	58	8.0	1534	5	-	-	-	0	-	-	-	5	-	-	-	0	0
Dairy	Lower	43	1,681		23	7.7	0.53	177	94	58	7.8	925	2	-	-	-	0	-	-	-	2	-	-	-	0	0
Dairy	Lower	45	1,753		33	8.2	0.61	271	165	-	-	937	2	-	-	-	0	-	-	-	2	-	-	-	0	0
Dairy	Lower	49	1,926		39	9.2	0.51	359	183	-	-	951	1	-	-	-	0	-	-	-	1	-	-	-	6	0
Dairy	Lower	54	2,098		18	7.1	0.81	128	104	-	-	1000	1	-	-	-	1	-	-	-	2	-	-	-	0	0
Dairy	Middle	124	5,130		43	11.8	0.86	507	436	60	9.0	1626	6	-	-	-	0	-	-	-	6	-	-	-	0	0
Dairy	Middle	126	5,223		12	12.0	0.85	144	122	-	-	1638	2	-	-	-	0	-	-	-	2	-	-	-	0	0
Dairy	Middle	129	5,298		25	7.3	0.90	183	164	-	-	1643	4	-	-	-	2	-	-	-	6	-	-	-	0	0
Dairy	Upper	247	10,207		28	5.8	1.11	162	180	63	6.0	1509	7	-	-	-	2	-	-	-	9	-	-	-	0	0
Dairy	Upper	255	10,496		33	8.3	1.15	274	315	-	-	1522	2	-	-	-	0	-	-	-	2	-	-	-	0	0
Dairy	Upper	261	10,699		28	9.5	0.63	266	168	-	-	1535	0	-	-	-	0	-	-	-	0	-	-	-	0	0
Pennington	Lower	53	2,273		29	5.8	0.98	168	165	59	8.0	941	2	-	-	-	0	-	-	-	2	-	-	-	0	0
Pennington	Lower	54	2,345		72	6.9	0.99	497	492	-	-	948	9	-	-	-	2	-	-	-	11	-	-	-	0	0
Pennington	Lower	58	2,469		29	8.0	1.09	232	253	-	-	959	8	-	-	-	0	-	-	-	8	-	-	-	0	0
Pennington	Middle	347/8	13,300		39	9.5	1.22	371	452	58	13.0	-	7	-	-	-	4	-	-	-	11	-	-	-	0	0
Pennington	Middle	350	13,361		26	5.9	0.57	153	87	-	-	1337	4	-	-	-	1	-	-	-	5	-	-	-	0	0
Pennington	Middle	352	13,403		19	8.5	0.91	162	147	-	-	1350	3	-	-	-	4	-	-	-	7	-	-	-	0	0
Pennington	Upper	546	20,054		22	7.8	1.51	172	259	-	-	1214	4	-	-	-	2	-	-	-	6	-	-	-	0	0
Pennington	Upper	553	20,397		25	8.0	0.78	200	156	57	9.0	-	6	-	-	-	2	-	-	-	8	-	-	-	0	0
Pennington	Upper	556	20,440		13	9.7	0.64	126	81	-	-	1138	3	-	-	-	0	-	-	-	3	-	-	-	0	0
Pennington	Upper	558	20,531		23	5.7	0.62	131	81	-	-	-	1	-	-	-	0	-	-	-	1	-	-	-	0	0

density in the eight (total) calibration pools of 1.8 fish/pool, which was much greater than the overall average density of 0.8 fish/pool in the 20 sampled pools. All of the 16 steelhead observed in Chorro Creek were greater than 10cm in length, which suggests that young-of-year steelhead do not rear in Chorro Creek during the fall months.

Table 2. Estimated abundance (with 95% confidence ranges) of juvenile steelhead in portions of Chorro Creek and Los Osos Creek, Morro Bay Watershed, California, 25-30 October 2001.

Creek	Area of Estimation	Length / Surf Area	Statistic	STH <10cm	STH 10cm+	All STH
Chorro	all pool habitats below	13,544 / 191,383	number	0	221	221
	Chorro Reservoir		variance	-	10,612	10,612
			95% conf range	-	16* - 437	16* - 437
Los Osos	diveable pool habitats	2,479 / 12,905	number	2,429	83	2,612
	in 3 reaches		variance	70,174	4,189	127,402
			95% conf range	1,875 - 2,983	13* - 218	1,865 - 3,359

* *lower range equals the number of fish observed*

The absence of young-of-year may be due to a predominance of spawning activity up in tributaries (we do not know the extent of spawning within Chorro Creek itself), or it may be associated with the presence of pikeminnow, possibly due to competition and/or predation. Dettman (1973) suggested that mechanisms other than competition, such as water temperature and flow, were more important in influencing the distribution and abundance of sympatric pikeminnows and trout in Deer Creek, California. Brown and Moyle (1991), however, found that juvenile steelhead were restricted almost exclusively to riffles in the presence of introduced pikeminnows in the South Fork Eel River, California, but not in a nearby tributary lacking pikeminnows. They postulated that the Eel River steelhead, which had not experienced pikeminnow or any other piscivorous fish in their recent evolutionary history, shifted habitat due to risk of predation. Pikeminnows, particularly individuals >18cm, are known to be highly piscivorous (Moyle 1976), and Brown (1990) found pikeminnow to become mostly piscivorous at lengths >10cm in one small stream in Northern California.

The overall estimate of abundance produced an average density of 94 steelhead per mile of pool habitat in the surveyed portions of Chorro Creek. Expanding that value to estimate the total number of steelhead in Chorro Creek would require an estimate of the relative densities of fish in run and riffle habitats. That data was not feasible to collect using snorkeling methodologies, however visual inspection of riffle habitats suggested that little to no suitable habitat occurred for steelhead due to extremely shallow depths. Run habitats, particularly in the lower portion of Chorro Creek, may have provided suitable rearing habitat for steelhead.

Figure 4 shows the estimated densities, converted to fish/mile, of steelhead and pikeminnow in each of the sampled pools in Chorro Creek. There is no discernable longitudinal trend seen in the densities of steelhead along Chorro Creek, however pikeminnow showed a general trend of decreasing densities with increased distance upstream. This trend was most evident for pikeminnows <10cm in length, whereas densities of larger pikeminnow (≥10cm) were consistently between 1,000 and 3,000 fish/mile throughout the lower nine miles of Chorro Creek. The exceptionally high density of pikeminnow (most of which were < 10cm) in Pool #55, RM 2.51 may be due to the relatively deep average depth of the pool (Table 1), and the large amount of instream willow cover. Although very large adult pikeminnows were not observed in Chorro Creek, some of the larger fish exceeded 20cm in length.

Pikeminnow were clearly the most abundant species in Chorro Creek, although threespine stickleback (*Gasterosteus aculeatus*) and speckled dace (*Rhynichthys osculus*) were also observed in high numbers, especially in the lower and middle portions of the creek. Two suckers (*Catostomus* sp.) approximately 20cm in length were also observed in one pool (Pool #55, RM 2.51) in the Chorro Flats area (Table 1).

Los Osos Creek

In contrast to Chorro Creek, all but one of the 20 sampled pools in Los Osos Creek contained steelhead (Table 1). The number of steelhead per pool ranged from 0 fish to 51 fish and averaged 12 fish/pool. The estimated total abundance of juvenile steelhead in all available pools within the surveyed areas of Los Osos

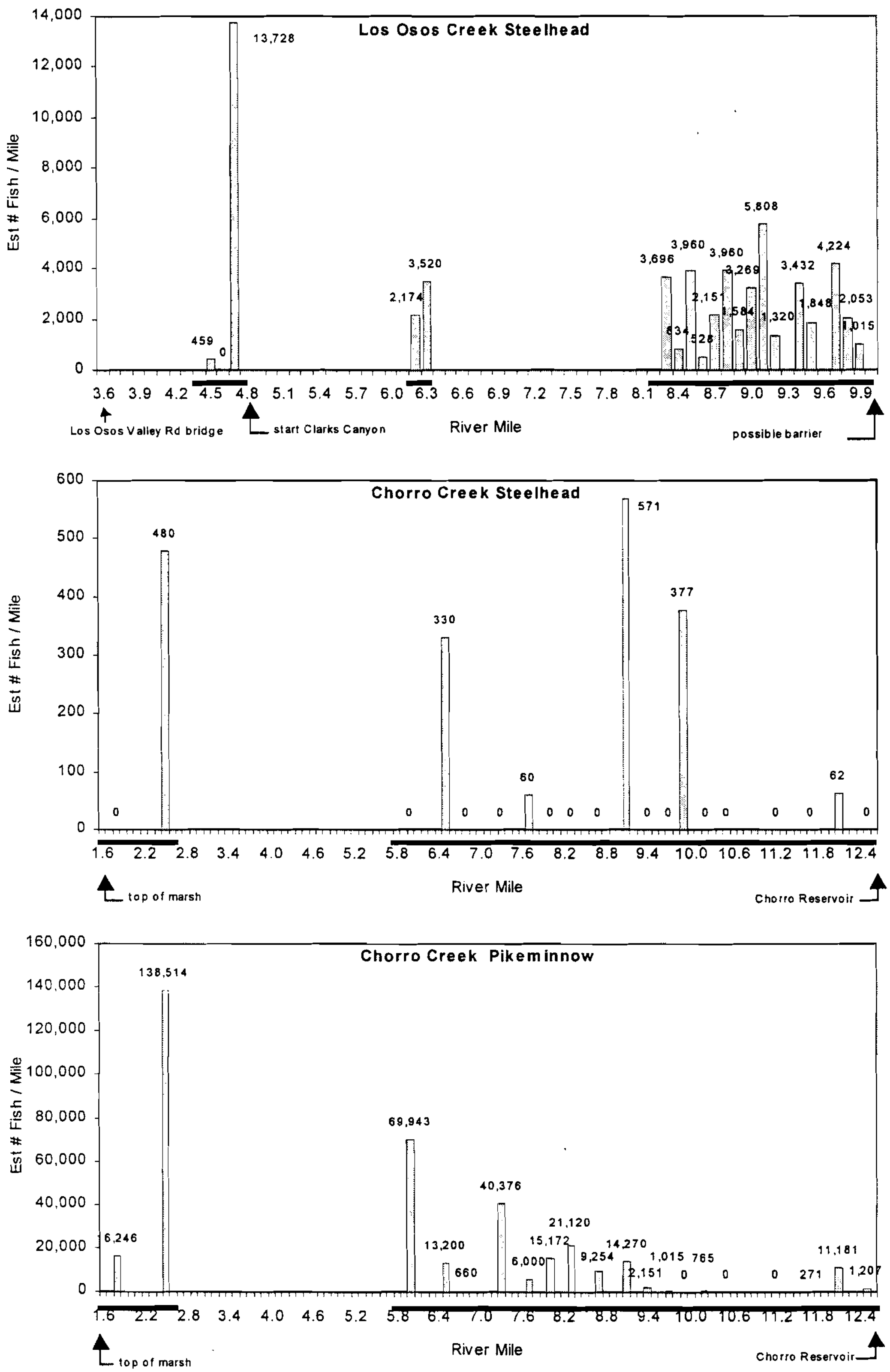


Figure 4. Estimated densities (#/mile) of steelhead and pikeminnow within pool habitats in Los Osos and Chorro Creeks, by river mile. Thick lines below x-axes represent survey area boundaries.

Creek was 2,612 fish with a 95% confidence range of 1,865 – 3,359 (Table 2). Los Osos Creek also differed from Chorro Creek in that the majority (95%) of 240 observed steelhead in Los Osos Creek were less than 10cm in length (most of those fish were <6cm). When the steelhead counts were partitioned into the two size classes, the estimated abundance of fish <10cm was 2,429 fish with a 95% confidence range of 1,875 – 2,983. The estimated abundance of steelhead ≥10cm in length was 83 fish with a 95% confidence range of 13 – 218 (the lower range equals the actual number of fish observed).

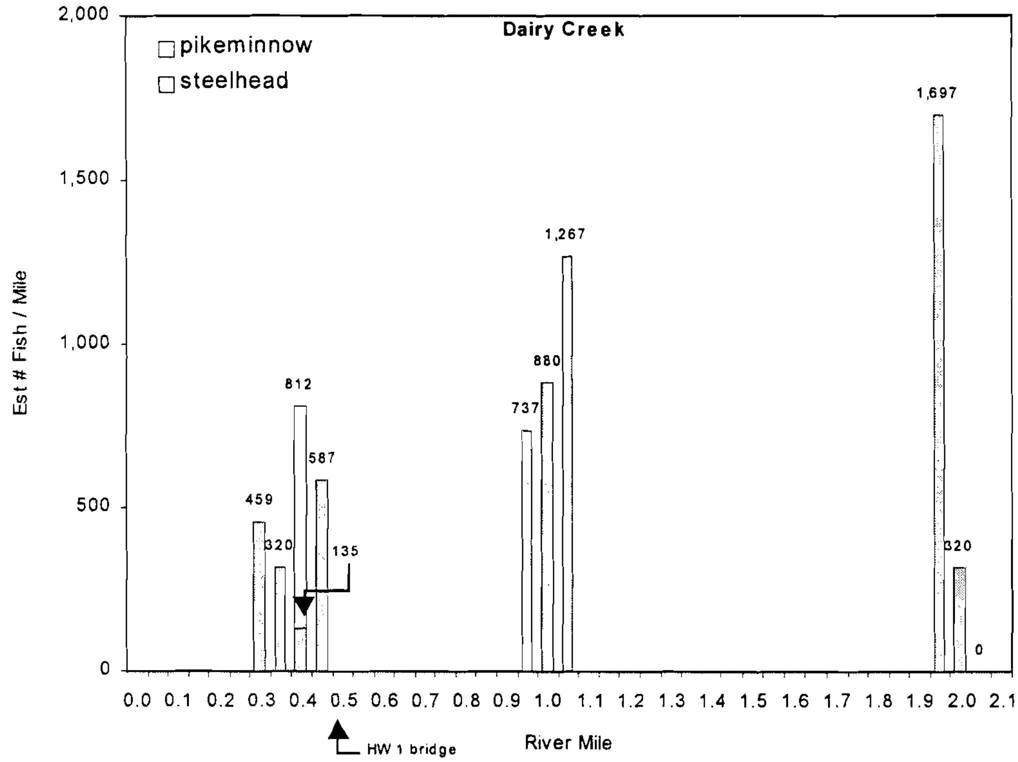
In general, steelhead densities (# per mile) were similar throughout the sampled area (Figure 4). One exception was Pool #56 from the Lower Reach that had a very high density possibly because it was a relatively deep pool at the very top of the wetted channel where fish may have been stacking up or becoming trapped. That pool was also within 30 feet of a dry tributary entering Los Osos Creek from the west, which may have recruited fish into the upper portion of that reach (Figure 2, Appendix A). The only other fish observed in Los Osos Creek were threespine stickleback, which were relatively abundant in each of the three reaches. The bedrock barrier observed near the top of the Upper Reach (Figure 3) appeared to prevent steelhead passage into upstream areas, however permissible access restricted the survey of only 1,000 feet above the barrier.

The overall estimate of abundance produced an average density of 2,978 steelhead per mile of diveable pool habitat in the wetted portions of the three study reaches. Expanding this value to estimate the total number of fish in Los Osos Creek would require an estimate of the total length of wetted stream available to steelhead, and the relative densities of fish in non-diveable pool habitats, run habitats, and riffle habitats. That data is not currently available, however visual inspection of run and riffle habitats suggested that little to no suitable habitat occurred for steelhead due to extremely shallow depths. Also, the majority of non-diveable pools in Los Osos Creek were very shallow and relatively few steelhead were observed in them.

Tributaries

A section of lower Warden Creek below "Warden Lake" was sampled but no fish were observed (Figure 2). This section of creek (~ 100 feet long x 20 feet wide) was very deep (4-6 feet) and channelized with no apparent flow, and contained very dark, tannic water. The creek was bounded on the left bank by a steep hill and on the right bank by agricultural fields with large eucalyptus trees dominating the riparian vegetation. The upper portion of Warden Creek was dry.

Steelhead were well distributed throughout the sampled areas of Pennington and Dairy Creeks (Figure 1). Steelhead densities (# per mile) were somewhat higher in Pennington Creek than in Dairy Creek, and densities appeared higher in the upstream areas than below Highway 1 (Figure 5). Average densities in both tributaries were roughly 10 times higher than average densities in Chorro Creek, but were less than average densities seen in Los Osos Creek. However, these are qualitative estimates based on relatively low sample sizes. There were no pikeminnow observed in Pennington Creek and they were seen in only one pool in the lower end (below Highway 1) of Dairy Creek. Threespine stickleback were also observed at the lower site in Dairy Creek while speckled dace were observed at the lower site of Pennington Creek.



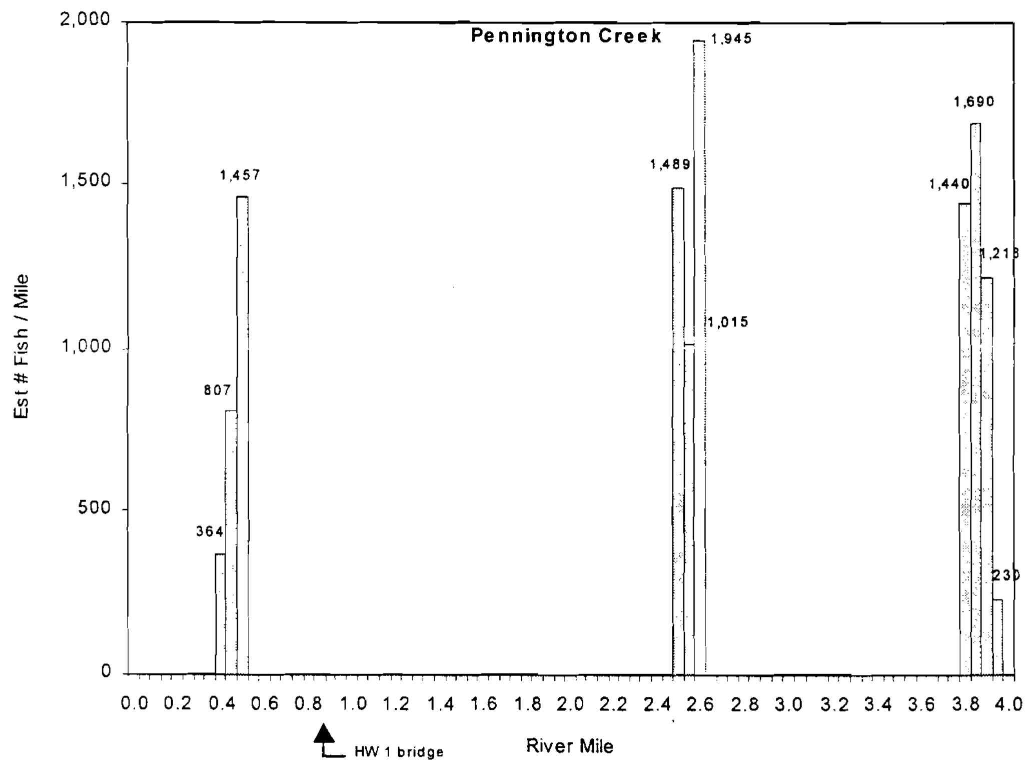


Figure 5. Estimated densities (#/mile) of steelhead and pikeminnow within pool habitats in Dairy Creek and steelhead only in Pennington Creek, by river mile.

Statement of Disclosure

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