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MERCED RIVER HABITAT TYPING, UNDERWATER FISH OBSERVATIONS, AND HABITAT RESTORATION RECOMMENDATIONS

YOSEMITE NATIONAL PARK

July, 1991

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U.S. Fish and Wildlife Service
Coastal California Fishery Resource Office
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Report AFF1-FRO-92-03
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TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

During July and August of 1991, approximately 15.7 km of the Merced River, and 3.9 km of side channels were habitat typed using the USFS, McCain et al. (1990) methodology, and channel types were designated using criteria prescribed by Rosgen (1985). Underwater snorkel fish counts were made on 6.2 km of the main channel, and 0.9 km of side channels. Information on streambank conditions, access points, and land use impacts was also documented.

A total of 17 habitat types comprised 344 main channel units, and 17 habitat types for 181 side channel units. The LGR (18.9%), CRP (12.8%), and LSP-log (11.9%) were the most common main channel units; for side channels, EGW (17.7%), LGR (16.0%), SCP (13.8%), and GLD (12.7%). Channel types were represented by B2, C2, C3, and C4. The C3 channel type was dominant in total mean length (2.5 km), followed by C4 (1.6 km) and C2 (1.3 km).

Underwater counts of 179 main channel habitat units resulted in 2,891 brown trout, 1,589 Sacramento suckers and 1,311 rainbow trout. Main channel fish abundance was highest in CRP and BSP, representing 24.0% and 16.1% of all fish, respectively. By species, rainbow and brown trout were most abundant in CRP, while juvenile suckers favored LSP-log, and adult suckers were equally common in CRP and LSP-log. Overall, with few exceptions, the three species tended to utilize the different habitat types in direct proportion to the availability of the habitats. Cover complexity was an determinant of fish abundance; habitats with the most complex cover elements had large woody debris and substantial depth.

An estimated 6.2 km (39.8% of the study area length) of Merced River's left and right banks were bare, exposed, or with little vegetation. The bare banks were associated with public access points, trails, and adjacent campground/cabin areas. Recreational use of the Merced River, roads/access systems, camping facilities, bridge structures, and instream modifications (e.g. rip-rapping) have resulted in complex impacts to the river's fishery and habitat.

Various habitat restoration measures, and the monitoring of these efforts are recommended. Sites undergoing current restoration as well as future sites should be graphically documented using the "redy-mapping" methodology. Underwater fish counts would accompany the mapping work. Collectively, these areas will constitute "index study sites", for monitoring the restoration efforts.

INTRODUCTION

Since the early history of Yosemite National Park (YNP), the Merced River within Yosemite Valley has sustained numerous alterations of its aquatic habitat, stemming primarily from cultural development, human visitation and related impacts. Presently, streambank erosion, soil compaction, and the scarcity of vegetation are readily apparent in high human use areas along the river.

In recent years, YNP began efforts to restore the fisheries and aquatic habitat of the Merced River. Restoration efforts have included removal of rip-rapping along the stream banks, riparian revegetation, stabilization of disturbed soils, elimination of the "put and take" plantings of hatchery trout, placement of stream-side trees (which are in high risk of toppling into the flood plain), fencing and closure of affected areas, removal of a historic dump site situated on the streambank, and allowing fallen trees to remain in the river. Various other activities are planned for the future.

During 1990, the U.S. Fish and Wildlife Service, Coastal California Fishery Resource Office (FWS) entered into a cooperative program with the YNP Resource Management staff to conduct fisheries baseline inventory work in the Merced River. The FWS agreed to perform habitat typing and direct observation work, and collect information that would be utilized by YNP towards their Merced River fishery restoration goals.

FISHERIES WORK PLAN

We recommend the following work plan as an initial template to monitor and evaluate the Merced River restoration program. The outlined work, and the recommendations provided within this report would be dependent upon funding and commitment of the FWS and YNP, and the cooperation of the California Department of Fish and Game (CDFG).

The habitat typing and direct observation field surveys completed during the summer of 1991 represent the first year of efforts by the FWS. This work serves as the initial base-line information, and these results are presented in this report. The results from the annual index site area surveys (to be selected during the summer of 1992) may then be compared with the base-line data. Any future physical and biological changes occurring in the Merced River may then be identified and compared quantitatively and qualitatively with the baseline and annual index site information. Substantial and consecutive annual changes identified in the index areas would necessitate repeating the comprehensive habitat survey for the entire study area (Pohono Bridge to the Happy Isles Footbridge). If significant habitat changes are not detected annually, within the index study sites, the intervals between the comprehensive surveys should be every four or five years.

During summer of 1992, several index study sites will be selected in the Merced River, using the habitat typing information that was collected during the summer of 1991. Additional index sites may be established in other areas of significant concern identified by the YNP staff. These significant areas will likely be sites that are undergoing or planned for habitat restoration.

Direct observation surveys will be performed annually on these index sites, thereby monitoring and evaluating the effects of the restoration activities on the fish populations and their habitat. As the YNP selects new sites for restoration work, we will incorporate these areas as new index sites. Previous index sites will be dropped when the monitoring and evaluation of individual restoration projects are considered complete.

The FWS will employ the U.S. Forest Service (USFS) "redy-map" methodology to annually chart the selected index area stream segments that are associated with active restoration projects. Stream segments other than the index areas may also be mapped if warranted by special circumstances. The mapping information will allow graphic representation of the progress of restoration efforts, and document any changes in the stream-banks and channel configuration that are resulting from the restoration work.

STUDY AREA

The 1991 field study took place in Yosemite Valley, within Yosemite National Park (Figure 1). The park covers an area of 55.7 square kilometers (km^2), and lies on the west slope of the Sierra Nevada range. The valley floor elevations range from 1,159 m to 1,281 m.

The Merced River is a tributary to the San Joaquin River. The Merced's headwaters originate on the westerly slopes of Mt. Lyell, Forester Peak, Isberg Peak, and Triple Divide Peak. The stream flows in a westerly direction through glaciated terrain, and drops dramatically onto the valley floor at Vernal and Nevada Falls. The stream's mean annual discharge, and mean low flow at the Happy Isles Bridge is 9.9 cubic meters per second (m^3/s), and 0.20 m^3/sec, respectively. The Merced River drains a basin approximately 516.6 km^2 at Pohono Bridge (Madej et al. 1991).

The Merced River study area ranged from the Pohono Bridge, upstream to the Happy Isles Gaging Station. The study area is an estimated 15.72 river kilometers (rkm) in length and is entirely within the Yosemite Valley floor area (Figure 1). The approximate stream elevation at the Pohono Bridge area is 1,177 m, and 1,225 m at the Happy Isles gaging station. The river is flanked by heavily utilized campgrounds and cabins, road networks, foot and horse trails, picnic areas, scenic vista parking areas, and spanned by numerous bridges. The Merced River also flows through picturesque meadows, and the El Capitan Moraine, a glacial moraine remaining from the most recent glaciation (10,000 years ago).

METHODS

CHANNEL TYPING AND HABITAT TYPING

Stream Closures and Public Interpretation

During the course of our study it was necessary to restrict visitor access from the portion of the stream undergoing examination on any particular day. The closures were necessary to insure that visitors to the stream did not disturb the fish, or impair the water clarity prior to the direct observation work.

The stream closures and public interpretation work was performed by a FWS volunteer and various YNP staff. Approximately 805 m of the stream was closed daily to public access, as the habitat typing and snorkeling work proceeded in the upstream direction (Figure 2). Signs and informative displays were posted at access points, and parking areas adjacent to stream reaches. The work activities and stream closures were mentioned at campfire talks, and other park forums.

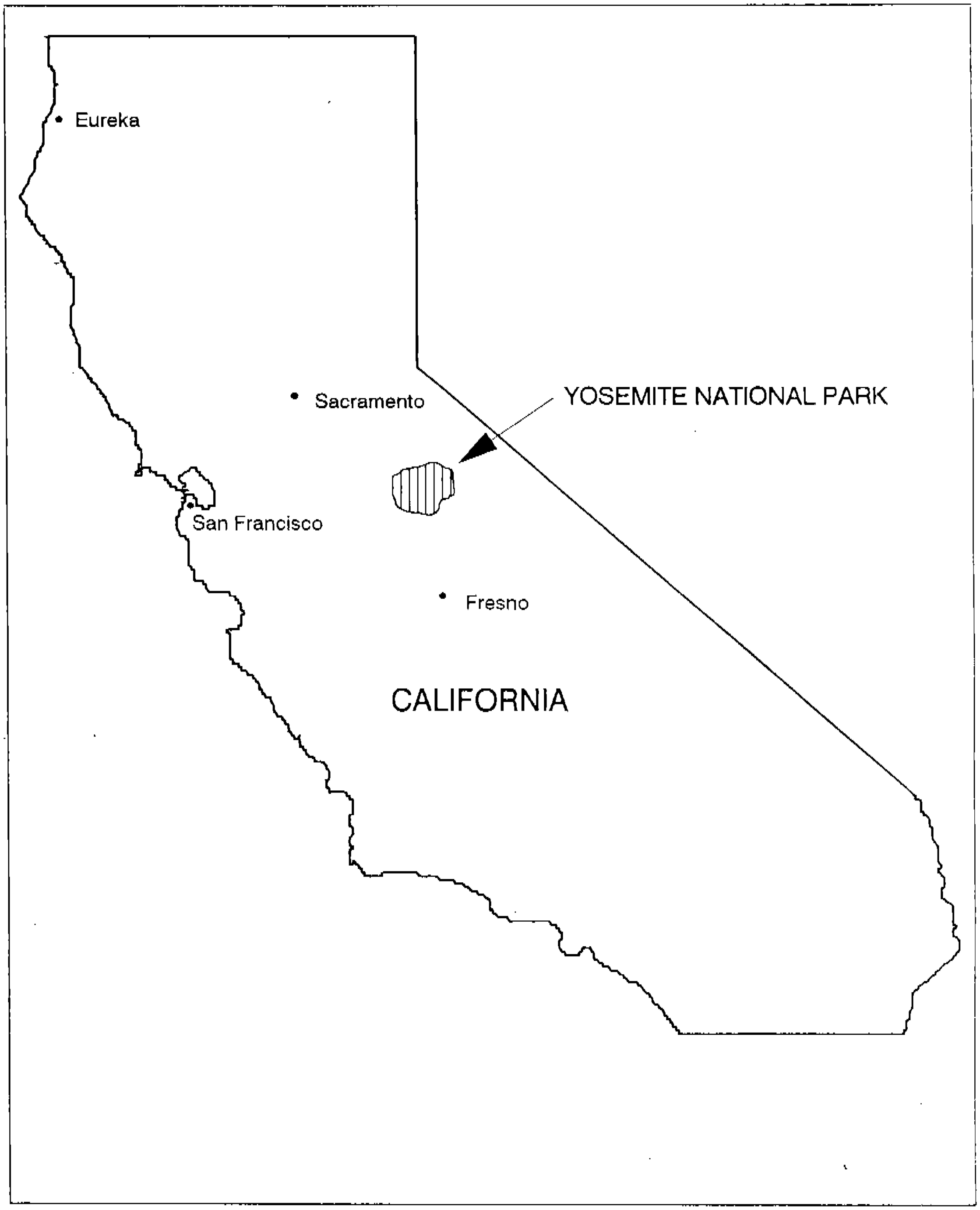

Figure 1. Location of Yosemite National Park, California.

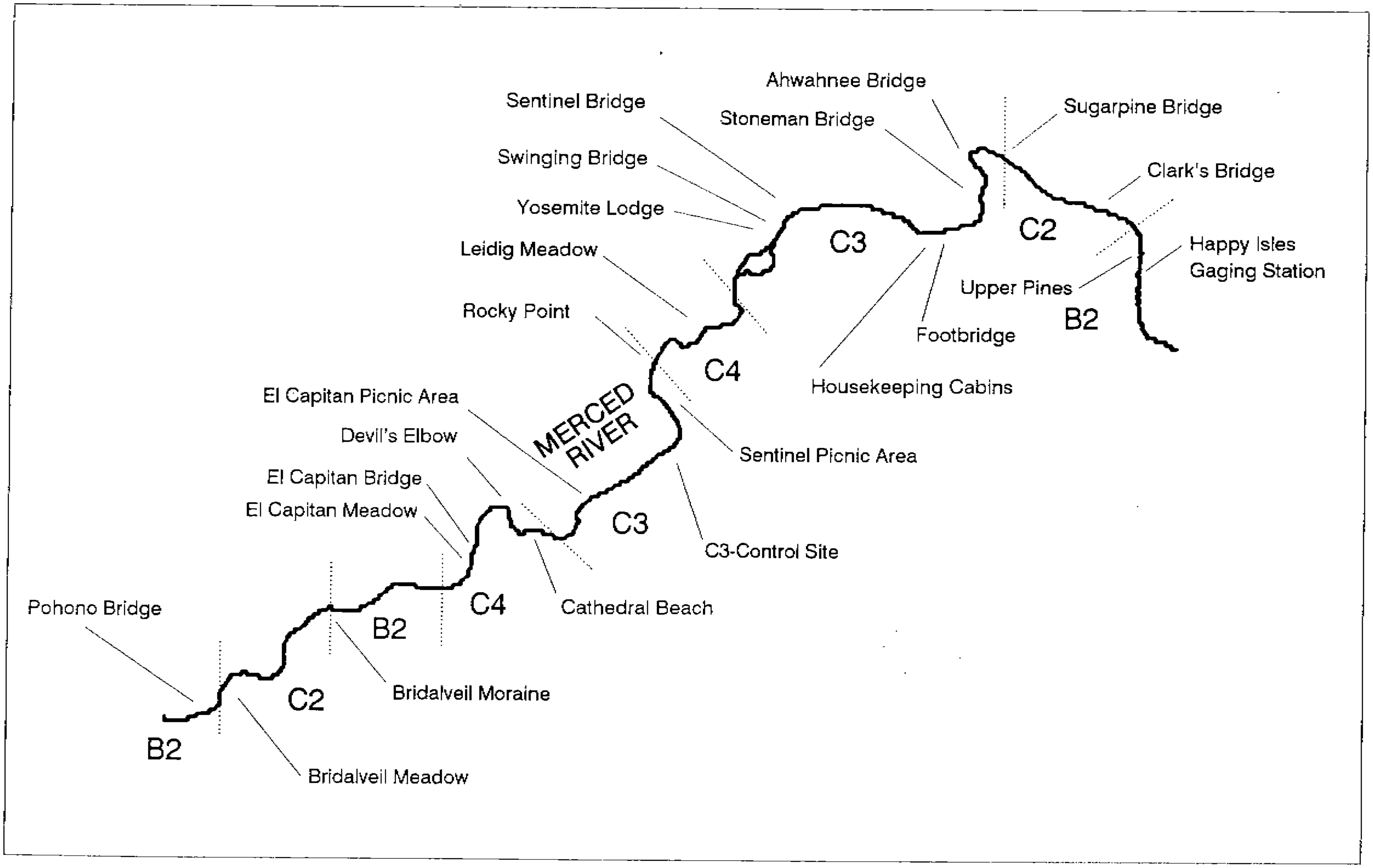

Figure 2. Map of the Merced River study area. Approximate locations of the different channel types are defined by dotted lines.

Channel Type Classification

The habitat typing and underwater direct observation work began on July 27, 1991, by a team of three FWS biologists and one FWS volunteer, and ended on August 23, 1991. The classification system of Rosgen (1985) was used for identifying channel type. The system categorizes channel types based upon landform, gradient, sinuosity, substrate size and composition, depth/width ratio, channel entrenchment and confinement, etc. (see Appendix A).

Habitat Typing

Habitat typing was done by two FWS biologists, and the direct observation (snorkel counts) was performed by a FWS biologist and one FWS volunteer. Stream morphology was categorized using methods presented originally by Bisson et al. (1982), and consequently modified by the U.S. Forest Service (USFS) (McCain et al., 1990). The USFS methodology was further modified slightly by FWS to suit specific needs of this Merced River inventory. Twenty-five distinct habitat types were available to categorize stream habitats (Appendix B).

Physical and biological measurements (see Appendix B) were taken in all habitat type units, in contrast to the standard 20% sampling rate normally utilized in the USFS methodology. This sampling rate provides a higher level of resolution to monitor base-line conditions and habitat changes to allow for future comparisons. A new habitat type, #25, bridge scour pool (BSP), was added to accurately describe the scoured habitats associated with bridges spanning the Merced River.

Although edgewater (EGW) habitat types may be associated with both main and side channel habitat units, for data analysis purposes, EGW units were assigned to and analyzed with other side channel habitat types. Inactive side channels (without standing or flowing water), and historical channels were not typed or measured for this survey.

Morphometric stream measurements (length, width, bankfull width, etc.) were estimated with hand-held rangefinders. Extremely long habitats exceeding the limits of the rangefinders necessitated multiple successive measurements to maintain accuracy of the estimates. Mean and maximum pool depths, and pool tail crest measurements were estimated with a stadia rod.

Habitat Evaluation and Land-use Impacts

Stream habitat assessment was based upon standard methods described by Platts et al. (1983). Substrate composition (see Appendix C), percent (%) substrate embeddedness, percent exposed substrate, overstory and understory vegetation was estimated visually. Mean left and right bank slopes (% slope) were estimated with a hand-held clinometer. Habitat units were assigned a cover complexity rating, 1-5; the 5 rating being the highest in complexity. This rating system provides a relative ranking of the complexity of the instream cover. The percent cover rating identifies the percentage of the entire habitat unit area that qualifies as cover for fish. The sum of the individual cover element percentages would equal the overall percent cover rating. This rating method allows for quantitative ranking of the individual cover elements.

In conjunction with the habitat typing, additional parameters were measured to help identify and quantify various streambank alterations resulting from cultural activities. The number of streambank access points, length of exposed (bare) left bank (LB) and right streambank (RB), and other related information was documented for future reference.

DIRECT OBSERVATION

The direct observation work was done with face masks and snorkels. Every third occurrence of each habitat type was sampled by two divers (33% sampling rate). Any unusual/unique habitat units were sampled as they occurred. The observations began about 2 hours behind the habitat typing team, at the bottom (downstream) end of the unit and proceeded upstream. The time lag was to allow fish to recover from the initial disturbance caused by the habitat typing crew.

Observed fish were identified to species, and their size categories were estimated. Trout visually estimated at 130 millimeters (mm) or less in length were assigned as "young-of-year" (YOY), while larger trout were designated "adults", although technically some of these trout may not become sexually mature for several months. The size categories for salmonids were utilized to maintain consistency with the work conducted by the CDFG in the Merced River.

Due to the high abundance and small size (usually less than 40 mm) of YOY suckers, only juvenile and adult suckers were counted. Size categories were arbitrarily assigned since specific age and growth information of the suckers in the Merced River is lacking. Suckers estimated in length from 50 to 200 mm were designated as juveniles, and larger suckers were "adults".

DATA COMPILATION AND ANALYSES

Field data was entered into dBase-III database for subsequent storage, retrieval and analysis. Analysis of the habitat types and direct observation counts was summarized by composite channel type, and consecutive channel types. The edgewater habitat (EGW) was lumped with the side channel units, and were analyzed separately from the main channel units.

RESULTS AND DISCUSSION

HABITAT TYPING

The habitat and direct observation results represent one replication, and are assumably influenced by (but not limited to) various factors such as observer bias, climatic regimes, stream discharge, and seasonal fish abundance.

During the work period, the Merced River flow discharge at the Happy Isles gaging station dropped from 2.83 cubic meters per second (m^3/sec) on July 27, to .85 m^3/sec by August 22, 1991. A stable, seasonal low flow period represents the most efficient conditions for performing the habitat typing work. Also, the low discharge conditions usually represents the harshest environmental conditions for trout populations. With significant changes in stream discharge, as observed during the typing work, certain habitat units can radically change, or disappear entirely, (e.g.) runs (RUN) may become low gradient riffles (LGR), EGW habitats may become dry, side channels may dewater, step runs (STP) may change into riffles, and other variable changes. Habitat types that are hydraulically controlled such as pools are less susceptible to changes in water surface elevation, and wetted perimeter, and therefore would not change its categorical type.

Changes in stream discharge also affects fish distribution. At low flows, the fish tend to concentrate in deeper habitats, and avoid shallow unprotected areas. The shift to higher densities usually improves the efficiency of the direct observation work.

However, for the purposes of this survey, any potential changes induced by the decrease in discharge probably would not limit the utility of this information as the initial year of base-line data. Although a certain amount of variation is in inherent with some of the objective assessments (such as substrate composition, cover components and complexity ratings), these categories are not expected to be influenced significantly by a drop in stage or stream flows. Visual assessments of substrates were hampered only in the deepest habitats (e.g. depths greater than 2.5 m).

Habitat Units-Main Channel

A total of 344 habitat units, comprising a total mean length of 15,722 m were identified for the main channel of the Merced River (Table 1). An additional 181 units (3,893.5 m total length) were identified for secondary channels, backwater units, and edge-water habitat units (Table 2, refer to Habitat Units-Side Channel section). The total mean length of the study reach may not equal known stream channel distances owing to variations in individual measurements, river sinuosity and configuration, and stream discharge.

Seventeen habitat types were observed in the main channel (Table 3). The most prevalent main channel habitat type was the LGR, constituting 18.9% of all types, followed by corner pools (CRP)(12.8%), lateral scour pools-log formed (LSP-log), and glides (GLD) were the third most abundant, each with an occurrence of 11.9%. The fourth most frequent (10.2%) habitat type was the RUN (Table 1). Three of these habitat types also comprised the greater percentages of total length: CRP (19.6%), GLD (14.7%), LGR (13.4%). The fourth longest was mid-channel pools (MCP), with a 12.9% occurrence.

By area (m^2), the CRP and GLD comprised 20.3% and 16.8% of the total area, respectively. The MCP ranked third (13.9%) in area.

Habitat Typing-Side Channel

A total of 17 distinct habitat types comprising 181 side channel units were identified (Table 3). Expectedly, side channel habitats differed markedly in size (length, width, max depths, etc.) from the main channel units. Although Edgewater (EGW) habitat types are identified as the most common side channel units, only two of the EGW were actually found in the side channels. This was an undesirable drawback of placing EGW units under the "side channel" category. Therefore, LGR units were actually the most common unit, followed by secondary channel pool (SCP) types, with frequencies of 16.0% and 13.8% occurrence, respectively. The total estimated area for the side channels was 36,556 m^2, or 9.4% of the total main channel area.

CHANNEL TYPING

Channel Type Sequence

There were four channel types encountered in the study reach: B2, C2, C3, and C4 (Table 4, Appendix C). The survey began at Pohono Bridge, and proceeded upstream; this area was in a B2 channel type. The next type (C2) began adjacent to the Bridalveil Meadow "Valley View" parking area. The overall stream gradient was less than the previous channel type. The channel type returned to B2 at the Bridalveil Moraine. Then, at the beginning of the El Capitan Meadow, the channel became a C4: sandy substrate, wide alluvial terrace, and slightly confined channel. This sub-reach was the second longest, with mean distance of 1,177 m. The next type, C3, began upstream of the Three Brothers Vista turnout (on Southside Drive). The dominant substrate was mostly gravel.

Table 1. Summary of main channel Merced River habitat types and measured (meters) parameters. Estimated mean and total areas in m^2, and mean and total volumes in m^3.

Habitat No.	Habitat Type	Number	Total %	Mean Length	Total Length	Total %	Mean Width	Mean Depth	Max Depth	Mean Area	Total Area	Mean Volume	Total Volume
1	LGR	65	18.9	32.4	2102.8	13.4	18.2	0.30	1.5	624.1	40567.7	165.2	10758.9
2	HGR	12	3.5	23.9	286.3	1.8	18.8	0.39	1.2	472.4	5671.7	187.6	2250.8
3	CAS	1	0.3	12.0	12.0	0.1	25.0	0.70	1.1	300.0	300.0	210.0	210.0
5	BWP-bo	1	0.3	35.0	35.0	0.2	28.0	1.80	2.8	980.0	980.0	1764.0	1764.0
9	PLP	1	0.3	16.0	32.0	0.1	32.0	1.00	1.7	512.0	512.0	512.0	512.0
10	LSP-log	41	11.9	43.2	1770.0	11.3	25.2	0.79	3.2	1194.8	48986.3	1076.2	44122.0
11	LSP-rtwd	16	4.7	36.6	585.0	3.7	21.7	0.77	3.3	901.0	14416.7	824.1	13185.8
13	DPL	1	0.3	23.0	23.0	0.2	12.0	0.15	0.3	276.0	276.0	41.4	41.4
14	GLD	41	11.9	56.1	2302.0	14.7	26.8	0.45	1.8	1593.1	65318.0	794.7	32584.3
15	RUN	35	10.2	29.7	1039.0	0.2	16.9	0.53	1.4	536.0	18761.3	282.9	9900.8
17	MCP	28	8.1	72.5	2031.0	12.9	24.7	0.97	3.4	1929.1	54014.4	2155.0	60339.8
19	CCP	2	0.6	27.2	54.5	0.4	20.0	0.75	1.5	528.8	1057.5	421.5	843.0
20	LSP-bo	25	7.3	26.2	655.1	4.2	15.5	0.76	2.1	428.0	11450.5	362.3	9056.5
21	POW	21	6.1	51.4	1080.0	6.9	22.2	0.58	1.6	1200.3	25206.0	769.3	16156.2
22	CRP	44	12.8	69.9	3076.8	19.6	24.5	1.12	4.4	1796.6	79050.5	2166.4	95323.2
23	STP	1	0.3	38.5	38.5	0.3	24.0	0.80	1.5	924.0	924.0	739.2	739.2
25	BSP	9	2.6	66.6	599.0	3.8	33.2	1.33	5.3	2338.9	21050.0	3368.6	30317.6
		344			15722.0						388542.3		328105.4

Table 2. Summary of side channel Merced River habitat types and measured (meters) parameters. Estimated mean and total areas in m^2, and mean and total volumes in m^3.

Habitat No.	Habitat Type	No. Units	%	Mean Length	Total Length	Total %	Mean Width	Mean Depth	Max Depth	Mean Area	Total Area	Mean Volume	Total Volume
1	LGR	29	16.0	16.1	466.8	12.0	7.3	.14	.64	135.9	3940.2	26.4	765.2
2	HGR	7	3.9	15.9	111.0	2.9	5.1	.14	.32	92.5	647.3	9.4	56.1
4	SCP	25	13.8	25.2	629.9	16.2	7.8	.41	3.80	207.6	5190.7	103.3	2582.2
5	BWP-bo	6	3.3	16.1	96.8	2.5	11.2	.78	2.00	217.2	1303.2	234.9	1409.1
6	BWP-rtwd	7	3.9	17.7	123.8	3.2	1.5	.76	1.80	140.6	984.2	145.5	1018.1
7	BWP-log	6	3.3	17.2	103.4	2.7	8.9	.56	1.60	161.9	971.2	130.0	779.8
9	PLP	2	1.1	4.7	9.3	.2	3.9	.21	.55	19.9	39.8	3.8	7.7
10	LSP-log	6	3.3	21.7	130.0	3.3	8.0	.46	1.70	190.1	1140.9	97.1	582.4
11	LSP-rtwd	10	5.5	9.6	95.5	2.5	5.4	.31	1.00	56.3	563.0	22.1	220.5
14	GLD	23	12.7	25.1	574.9	14.8	8.5	.20	.90	237.7	5467.8	61.4	1411.1
15	RUN	9	5.0	20.7	186.0	4.8	5.3	.22	1.30	125.1	1125.7	37.1	334.2
17	MCP	5	2.8	25.0	125.0	3.2	7.8	.52	1.00	187.7	938.7	96.6	482.9
18	EGW	32	17.7	27.2	871.4	22.4	9.3	.23	.95	275.0	8799.5	73.7	2359.2
19	CCP	2	1.1	27.5	55.0	1.4	9.4	1.03	1.10	269.1	538.2	357.4	714.8
20	LSP-bo	3	1.7	22.9	68.8	1.8	7.1	.50	1.20	163.3	489.8	103.4	310.2
21	POW	2	1.1	33.2	66.4	1.7	6.5	.28	.60	164.8	329.5	49.0	72.1
22	CRP	7	3.9	25.6	179.5	4.6	8.6	.37	1.10	230.9	1616.2	93.5	654.7
		181			3893.5						34085.9		13760.3

Table 3. Merced River main and side channel fish counts by habitat type, for species and life stage, and number of units snorkeled.

Main Channel

Habitat No.	Habitat Type	Number of Units	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult	TOTAL
1	LGR	10	49	1	125	3	6	12	196
2	HGR	4	27	1	6	2	0	0	36
5	BWP-bo	1	3	0	0	10	0	0	13
9	PLP	1	9	2	18	4	1	4	38
10	LSP-log	14	81	7	284	42	192	251	857
11	LSP-rtwd	4	15	3	127	5	31	0	181
14	GLD	11	54	1	212	43	91	33	434
15	RUN	13	80	11	147	11	1	4	254
17	MCP	11	136	19	373	64	55	172	819
19	CCP	1	29	1	19	0	0	0	49
20	LSP-bo	8	127	16	133	11	13	12	312
21	POW	8	127	11	45	15	28	33	259
22	CRP	13	273	48	538	120	158	252	1389
23	STP	1	11	4	3	0	0	2	20
25	BSP	9	134	31	430	101	48	190	934
		109	1155	156	2460	431	624	965	5791

Side Channel

Habitat No.	Habitat Type	Number Units	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult	TOTAL
1	LGR	3	3	0	1	0	0	0	5
2	HGR	1	0	0	0	0	0	0	0
4	SCP	7	12	0	77	1	14	0	104
5	BWP-bo	2	13	0	7	0	3	0	23
6	BWP-rtwd	4	20	2	41	3	6	9	81
7	BWP-log	2	1	0	6	0	0	0	7
10	LSP-log	3	9	0	30	0	5	0	44
11	LSP-rtwd	3	5	2	23	2	1	0	33
14	GLD	3	16	0	22	0	3	0	41
17	MCP	4	1	0	33	0	5	0	39
18	EGW	6	4	0	11	0	0	0	15
20	LSP-bo	1	9	0	0	0	0	0	9
21	POW	1	0	0	4	0	0	0	4
22	CRP	2	8	0	50	3	1	0	62
		42	143	4	305	9	38	9	466

Table 4. Fish counts by species and life stage for the main and side channels of the Merced River. Fish counts by sequential and composite channel type for the main and side channels Merced River.

	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult	Total
Main Channel	1155	156	2460	431	624	965	5791
Side Channels	101	4	305	9	38	9	466
Total Counts	1256	160	2765	440	662	974	6257

Main Channel-Sequential Channel Type

	Length Meters	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult	Total
B2	232.0	32	1	14	17	1	0	65
C2	682.8	134	15	64	13	0	39	265
B2	282.5	90	9	26	1	11	57	194
C4	1177.0	59	5	273	34	175	276	822
C3	677.5	43	10	392	30	175	80	730
C4	407.0	38	0	140	18	9	73	278
C3	1860.1	284	60	1179	237	210	409	2379
C2	590.0	303	28	313	63	19	29	755
B2	328.0	172	28	59	18	24	2	303
	6236.9	1155	156	2460	431	624	965	5791

Main Channel-Composite Channel Type

	Length Meters	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult	Total
B2	842.5	294	38	99	36	36	59	562
C2	1272.8	437	43	377	76	19	68	1020
C3	2537.6	327	70	1571	267	385	489	3109
C4	1584.0	97	5	413	52	184	349	1100
	6236.9	1155	156	2460	431	624	965	5791

Side Channel-Composite Channel Type

	Length Meters	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult	Total
B2	115.8	18	0	24	0	3	0	45
C2	228.2	10	2	9	2	11	0	34
C3	281.5	30	2	84	3	6	0	125
C4	364.2	43	0	188	4	18	9	262
	989.7	101	4	305	9	38	9	466

The channel type returned to C4 at Rocky Point, immediately upstream of the power transmission corridor. The next type, C3, began at the Swinging Bridge; this sub-reach (from the Swinging Bridge upstream to the island immediately downstream of Sugarpine Bridge) was the longest (1,860 m) individual channel type in the survey.

The next type (C2), from the island upstream, ended upstream of the Medial Moraine, adjacent to the Upper Pines Campsites. The final segment of river, ending at the Happy Isles Gage Bridge was in a B2 channel type.

The distribution of the habitat types by channel type are presented in Table 4. For the combined three B2 channel segments, pocket water (POW) and lateral scour pool-boulder (LSP-bo) comprised 22.6 and 17.6% of their total habitats, respectively. This channel type was associated with the higher gradient, moderately confined segments described previously. In the C2 type, LGR (28.9%) and RUN (17.1%) habitats prevailed. For C3, the most common habitat types were LGR (19.4%) and CRP (18.0%). El Capitan Meadow and Leidig Meadow were associated with the C4 channel type; LSP-log (32.8%) and CRP (17.9%) were the most common habitat types. The prevalence of CRP in the C3 and C4 types reflects the higher degree of sinuosity associated with these channel types.

Substrate Composition

Substrate composition of habitat types in the B2 channel types were dominated by boulders, cobble, and sand. An example of the B2 channel type area would be the Bridalveil Moraine. For the C2 channels, cobble substrate was dominant, followed by boulders and gravel. In the C3 channel types, gravel was dominant, with sand and cobble ranking second and third, respectively. For type C4, gravel and sand were about equal in dominance, and fines followed in rank. El Capitan and Leidig meadows occurred adjacent to C4 type channels. For these respective channel types, the observed particle size and compositions were consistent with criteria outlined in Rosgen's (1982) channel type classification system.

Channel Type-Side Channels

Of 181 side channel units, 31 units were in the B2 type, 44 units in C2, 65 units in C3, and 38 units in C4. For the B2 and C2 side channels, LGR habitats were the most common (25.8% and 25.0%), respectively. The C2 channels had the most diverse representation of habitat types, with the exception of some backwater pool (BWP) type categories, plunge pools (PLP), and LSP-log units (Table 5). Plunge pools (PLP) were most common in C3, and BWP types were more common in this channel type than the others. The C4 side channel was similar to its main channel counterpart, having more woody debris than the other channel types. This was reflected in the relative abundance of LSP-log, LSP-rtwd (rootwad), and BWP-rtwd habitat types.

DIRECT OBSERVATION

Direct observation counts can identify the relative abundance of fish, and are readily duplicated, provided that variation from observer bias and environmental conditions can be minimized. Attempts to quantify population size based upon this method have limited utility unless the counts can be calibrated with an alternative method, such as electro-fishing. Also, visual methods tend to under-estimate the actual abundance of smaller fish. Any inferences or conclusions need to be weighed by the consideration that these observations were representative of low discharge conditions, and may not reflect habitat usage at higher discharge levels. Despite these limitations, the observations provide helpful information on relative abundance, distribution and species composition.

Table 5. Merced River main and side channel habitat types by channel types. Percent occurrence of habitat type per channel type.

Main Channel

Habitat No.	Habitat Type	No. Units	B2	%	C2	%	C3	%	C4	%
1	LGR	65	6	9.7	22	28.9	27	19.4	10	14.9
2	HGR	12	8	12.9	3	3.9	1	.7	0	0
3	CAS	1	1	1.6	0	0	0	0	0	0
5	BWP-bo	1	1	1.6	0	0	0	0	0	0
9	PLP	1	0	0	0	0	1	.7	0	0
10	LSP-log	41	1	1.6	1	1.3	17	12.2	22	32.8
11	LSP-rtwd	16	2	3.2	2	2.6	7	5.0	5	7.5
13	DPL	1	0	0	1	1.3	0	0	0	0
14	GLD	41	2	3.2	7	9.2	24	17.3	8	11.9
15	RUN	35	8	12.9	13	17.1	11	7.9	3	4.5
17	MCP	28	4	6.5	6	7.9	12	8.6	6	9.0
19	CCP	2	1	1.6	1	1.3	0	0	0	0
20	LSP-bo	25	11	17.7	6	7.9	8	5.8	0	0
21	POW	21	14	22.6	7	9.2	0	0	0	0
22	CRP	44	1	1.6	6	7.9	25	18.0	12	17.9
23	STP	1	1	1.6	0	0	0	0	0	0
25	BSP	9	1	1.6	1	1.3	6	4.3	1	1.5
		344	62		76		139		67	

Side Channel

Habitat No.	Habitat Type	No. Units	B2	%	C2	%	C3	%	C4	%
1	LGR	29	8	25.8	11	25.0	8	12.3	2	5.3
2	HGR	7	2	6.5	5	11.4	0	0	0	0
4	SCP	25	1	3.2	2	4.5	16	24.6	6	15.8
5	BWP-bo	6	2	6.5	2	4.5	1	1.5	1	2.6
6	BWP-rtwd	7	0	0	0	0	5	7.7	2	5.3
7	BWP-log	6	1	3.2	0	0	5	7.7	0	0
9	PLP	2	2	6.5	0	0	0	0	0	0
10	LSP-log	6	1	3.2	0	0	1	1.5	4	10.5
11	LSP-rtwd	10	4	12.9	2	4.5	0	0	4	10.5
14	GLD	23	3	9.7	2	4.5	10	15.4	8	21.1
15	RUN	9	2	6.5	1	2.3	3	4.6	3	7.9
17	MCP	5	0	0	1	2.3	0	0	1	2.6
18	EGW	32	5	16.1	10	22.7	13	20.0	4	10.5
19	CCP	2	0	0	1	1.3	0	0	1	2.6
20	LSP-bo	3	0	0	3	6.8	0	0	0	0
21	POW	2	0	0	2	4.5	0	0	0	0
22	CRP	7	0	0	2	4.5	3	4.6	2	5.3
		181	31		44		65		38	

Main Channel Counts-Habitat Type

During the field surveys, 179 habitat units were snorkeled, representing 137 main channel units, and 42 side channel units. The 137 units totaled 6,236.9 m average length, or 39.7% of the entire main channel length (15,722 m). Relative to the 344 total main channel units, the 137 units snorkeled constitutes 39.8% of the main channel units.

Brown trout were the most commonly observed species (2,891 fish) and composed 49.9% of all fish observed in the main channel, followed by 1,589 Sacramento suckers, and 1,311 rainbow trout (Table 4). Brown trout were commonly distributed throughout all units snorkeled, while rainbow trout were uncommon throughout all the units snorkeled. Adult rainbow trout were generally more prevalent in the steeper gradient areas.

The highest numbers of fish were observed in pools (CRP and BSP), accounting for 24.0% and 16.1%, respectively, of all fish (Table 3). For rainbow and brown trout, YOY and adults of both species were most common in CRP, consisting of 267 YOY and 134 adult rainbows, and 404 YOY and 120 adult browns, respectively. Sucker juveniles were most abundant (192) in lateral scour-log formed pools (LSP-log), while the most adults were counted in the CRP (252) and LSP-log (251) habitat types. The CRP and BSP habitat types contained 25.0% and 17.9% of all salmonids observed, respectively. These habitats had adequate depth, and some CRP had good cover in the form of undercut banks, ledges, and woody debris.

The CRP, constituted 12.8% occurrence of all habitat types, and 20.3% of the total area of habitats surveyed (Table 5). The BSP comprised only 2.6% of all units, and 5.4% of the total area. Yet 16.9% of all fish observed, and 17.9% of all salmonids counted were found in the BSP habitat type. The BSP habitats are probably providing depth, cover, and food for the fish.

With a few specific exceptions, the three species of fish generally utilized the habitat types in proportion to the availability of these habitats (Figure 3). The underwater counts indicate that CRP habitats were heavily utilized by all fish (Table 6). For salmonids, the CRP and BSP habitats held the highest numbers of fish. Suckers displayed an affinity to LSP-log formed habitats, where 27.9% of all suckers were observed. The results also suggest that brown trout and sucker did not "favor" LSP-bo and POW habitats, whereas usage by rainbow was relatively higher. This may be related to the higher water velocity characteristics of these habitat types, which rainbow are known to inhabit. Despite this, all three species of fish displayed low usage in LGR, high gradient riffle (HGR), and POW habitats. This observed "under-utilization" or negative "selection" of these habitats may be related to two plausible factors. In riffles with larger (cobble) substrates, fish would be more difficult to observe, and thus would be under-represented in the observations. Secondly, fish may be seasonally emigrating from these habitats with decreasing stream discharge; particularly the adult life stages.

The direct observation results (main channel) indicate that for YOY and adult trout, brown trout were the dominant salmonid in virtually every habitat type. However, the ratio of YOY rainbow trout to YOY brown trout (rainbow:brown) was not as disparate as the adult ratio. The ratio YOY rainbow and YOY brown trout abundance was .470, and for adults, the ratio was .362. Various explanations are possible: the ratio may indicate differential survival of the two species to the adult stage; perhaps adult rainbow are more susceptible to harvest, or predation. Differential harvest of rainbow trout may be a plausible explanation for their lesser abundance. Brown trout generally are less susceptible to angling harvest than their less warier rainbow counterparts.

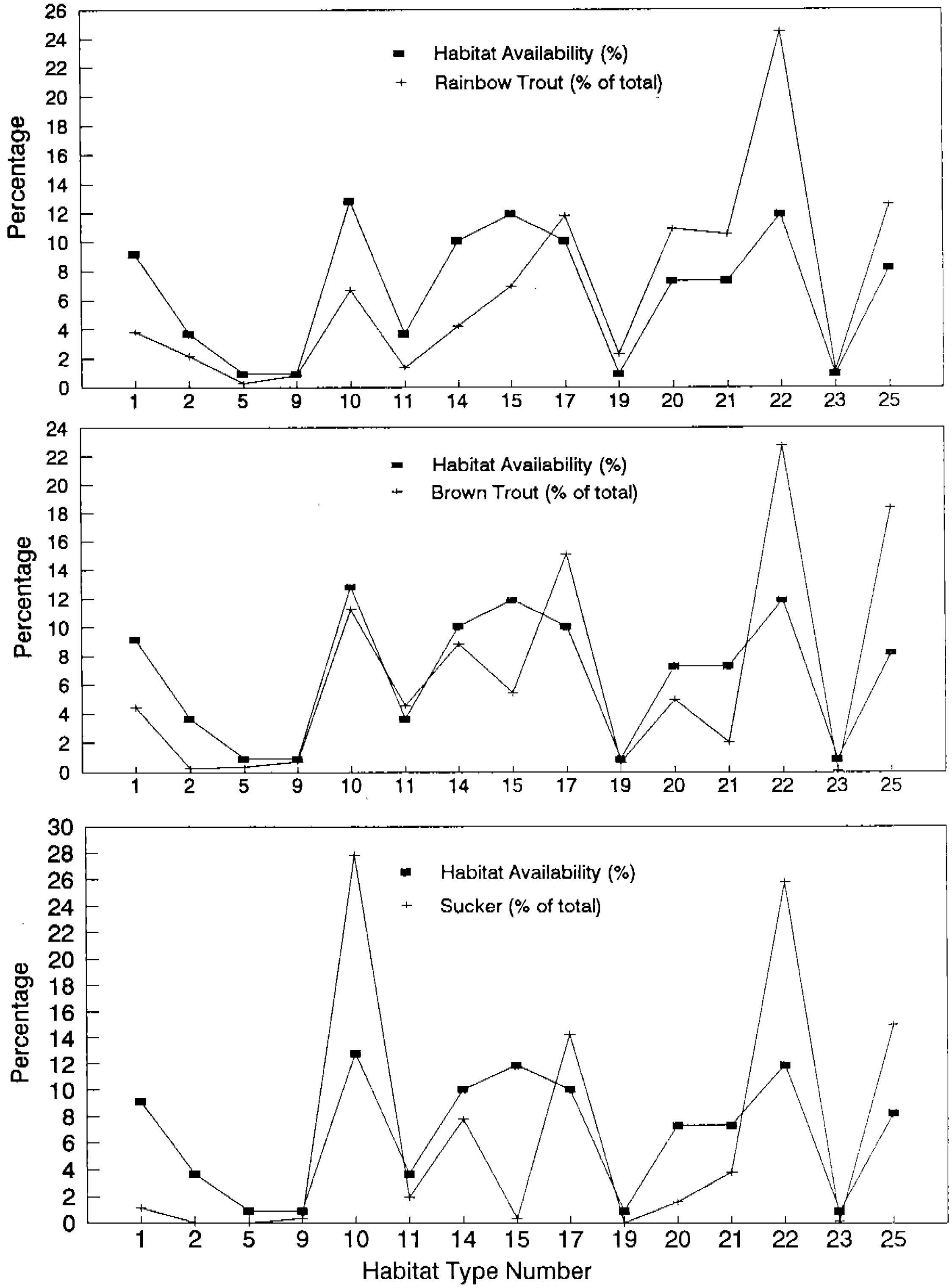

Figure 3. Habitat availability (percent occurrence) of main channel habitat type, and percent of fish observed per habitat type, for rainbow and brown trout, and Sacramento sucker.

Table 6. Habitat units snorkeled in the main channel Merced River. Percent habitat occurrence, number and percentage of fish observed by habitat type and species, based on main channel fish counts by habitat type.

Habitat No.	Habitat Type	No. Units	Percent Habtype	Rainbow Total	Rainbow %	Brown Total	Brown %	Sucker Total	Sucker %
1	LGR	10	9.17	50	3.81	128	4.43	18	1.13
2	HGR	4	3.67	28	2.14	8	.28	0	0
5	BWP-bo	1	.92	3	.23	10	.35	0	0
9	PLP	1	.92	11	.84	22	.76	5	.31
10	LSP-log	14	12.84	88	6.71	326	11.28	443	27.88
11	LSP-rtwd	4	3.67	18	1.37	132	4.57	31	1.95
14	GLD	11	10.09	55	4.20	255	8.82	124	7.80
15	RUN	13	11.93	91	6.94	158	5.47	5	.31
17	MCP	11	10.09	155	11.82	437	15.12	227	14.29
19	CCP	1	.92	30	2.29	19	.66	0	0
20	LSP-bo	8	7.34	143	10.91	144	4.98	25	1.57
21	POW	8	7.34	138	1.53	60	2.08	61	3.84
22	CRP	13	11.93	321	24.49	658	22.76	410	25.80
23	STP	1	.92	15	1.14	3	.10	2	.13
25	BSP	9	8.26	165	12.59	531	18.37	238	14.98
		109		1311		2891		1589	

Other fish species were not seen in our survey. The presence of riffle sculpin (Cottus gulosus) was first documented in 1934, near the Arch Rock area (Evans et al. 1961), and presently does not appear to have successfully invaded the valley floor area. Riffle sculpins were not found by CDFG during their 1990 and 1991 electro-fishing surveys. Tahoe suckers (Catostomus tahoensis) were illegally introduced into Tenaya Lake, but there is no present indication that they have emigrated downstream into the Merced River (J. Smith, pers. comm. 1992).

Main Channel Counts-Channel Type

The highest number of fish (2,549) were seen in the C3 channel type, followed by C2 (949), and C4 (928) (Table 4). By species, rainbow trout were seen most frequently in C2 (480) and C3 (387) channel types; and for brown trout, in the C3 (1,838) and C2 (465) channels, respectively. Sacramento suckers were observed most in types C3 (874) and C4 (337). By species and life stage, the C2 channel type seemed to be favored by rainbow YOY, and C3 contained the most brown YOY. Sucker juveniles were most abundant in the C3 category. The adults of all three species were most common in C3. These counts are the total number of fish seen by each channel type segment. The channel type segments were unequal in length, and the numbers are not standardized, thus they do not reflect the relative density of fish.

On a standardized fish per mile (fish/1.61 km) density basis, the results were quite variable. The highest density of rainbow trout was in the B2 channel type, and the C3 channels was the most favorable for brown trout and suckers (Table 7). Densities are given in fish/mile to maintain consistency with CDFG methods.

The number of salmonids per square meter (m^2) also varied for each channel type, but were generally within a narrow range (.025-.029 fish/m^2), with the exception of C4 (.009 fish/m^2). The percentage of cover and cover complexity (discussed in the Habitat section) were examined in an effort to identify possible determinants of fish abundance and density. The lower densities of salmonids in the C4 channel type could not be attributed entirely to the low percentage of cover (mean of 18.8%) for this type, since the percentage of cover for the C3 channel type was also similar (18.3%; B2 was 48.7%, and C2, 40.5%). Other factors may be involved, such as food availability, velocity and flow, temperature, and cover complexity.

Rainbow YOY densities were highest in the B2 and C2 types, .016 and .014 fish/m^2, respectively. The C3 and C2 types held the highest concentration of brown YOY, .016 and .011 fish/m^2, respectively. Sacramento suckers were most prevalent in C3 (.006 fish/m^2), and C4 (.004 fish/m^2) channel types.

Fish Counts-Side Channel

Forty-two side channel units, representing 14 different habitat types, were snorkeled. A mean distance of 990 m was snorkeled, representing 25.4% of the total side channel mean length of 3,893.5 m. A total of 466 fish were counted (Tables 3,5). The overall density of fish was .024 fish/m^2, and .019 salmonids/m^2. Of all fish observed in the side channels, 22.3% were observed in SCP, 17.4% in BWP-rtwd, and 9.4% in LSP-log habitats. Brown trout were also the dominant species in the side channels. During the survey, adult salmonids were uncommon in the side channels, most likely due to the limited amount of habitat resulting from seasonal low flows. During periods of higher discharge, the side channels probably are nursery areas for YOY, spawning areas, and also provide adult habitat.

Young-of-year suckers were very abundant in certain backwater and edgewater habitats. These areas were not actively occupied by YOY trout; during the survey period, cover, depth and water temperatures did not appear favorable

Table 7. Observed fish densities in mean fish per mile by species and life stage for the main and side channels of the Merced River. Fish densities by sequential and composite channel type for the main and side channels Merced River. Densities apply to snorkeled habitats.

Fish per Mile for Main and Side Channels

	Mile	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult
Main Channel	3.88	298	40	634	111	161	249
Side Channels	.61	166	7	500	15	62	15
Total Counts	4.49						

Fish per Mile by Sequential Channel Type

	Length Meter	Length Mile	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult
B2	232.0	0.14	222	7	97	118	0	7
C2	682.8	0.42	316	35	151	31	0	92
B2	282.5	0.18	513	52	148	6	63	325
C4	1177.0	0.73	81	7	373	46	239	377
C3	677.5	0.42	102	24	931	71	416	190
C4	407.0	0.25	150	0	554	71	36	289
C3	1860.1	1.16	246	52	1020	205	182	355
C2	590.0	0.37	826	76	854	172	52	79
B2	328.0	0.20	844	138	289	88	118	10
	6236.9							

Fish per Mile by Composite Channel Type

	Length Meter	Length Mile	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult
B2	842.5	0.52	562	73	189	69	69	113
C2	1272.8	0.79	553	54	477	96	24	86
C3	2537.6	1.58	297	44	996	169	244	310
C4	1584.0	0.98	99	5	420	53	187	355
	6236.9	3.88						

Fish per Mile by Composite Side Channel Type

	Length Meter	Length Mile	Rainbow YOY	Rainbow Adult	Brown YOY	Brown Adult	Sucker Juv	Sucker Adult
B2	115.8	0.07	250	0	334	0	42	0
C2	228.2	0.14	71	14	63	14	76	0
C3	281.5	0.17	172	11	480	17	34	0
C4	364.2	0.23	190	0	831	18	35	40
	989.7	0.61						

for YOY salmonids.

HABITAT EVALUATION

Habitat Cover Complexity

Of 344 main channel habitat units, 341 units were assigned a cover complexity rating to 17 distinct habitat types. By percentage, 53.4% of the main channel units with assigned ratings had a cover complexity of 1, 37.0% rated 2, 9.1% were rated 3, and 0.06% received a 4 rating. The majority of the units with ratings of 1 and 2 were due to whitewater and/or boulders providing cover for fish. The higher complexity ratings were most frequently from the additional presence of woody debris and water depth (>1.0 m). For the more common habitat types of 20 units or more, the habitat types with the most complex cover ratings were CRP, LSP-log, and LSP-bo.

A trend between cover complexity and fish numbers (mean number of fish per habitat) was inferred from the direct observations. Habitat units with higher cover complexity ratings had higher numbers of fish; this applied to the three species, and for the YOY and adult stages (Figure 4). Additionally, fish were more abundant in LSP-log, MCP, CRP, and BSP habitat types; these habitats displayed greater mean depths and cover complexity.

The percentage of cover category did not adequately explain fish abundance or density. The cover complexity ratings appears to be a better determinant of fish abundance and/or habitat utilization, perhaps because it rates the quality of the overall habitat (by evaluating cover components) rather than its quantity.

Habitats with elements of cover are also providing shade, food, diverse stream flow patterns, and protection for fish from predation (birds, mammals, larger fish, etc.). These results support the importance of quality cover for fish.

Salmonid Spawning Habitat

Areas with extensive (>2 m^2) suitable spawning gravel for salmonids were identified during the field survey. Areas with "micro" pockets of gravel were not noted. Spawning habitat was associated with 26 distinct units, 16 units in the main channel, and 10 in the side channels. Ten of the 16 main channel units were LGR. Three of the 10 side channel units were also LGR, and 3 other units were RUN. For the non-riffle habitats, primarily pools, the spawning gravels were usually found at the tail-outs of the units. Also, suitable gravels were associated with submerged and partially buried logs in the channel.

Relative to the number of habitat units in the main channel, areas with spawning gravels were scarce. Spawning gravels were much more common in the side channels. This raises the question whether trout are spawning only in the main and side channel areas, and tributaries with extensive gravels, or are also spawning opportunistically wherever adequate gravels exists. Often, "micro" pockets of gravel may be associated behind larger cobble, boulders, and in lateral margins of the stream channel.

Habitat typing work is done during seasonal low flows, which would under-estimate the total potential areas actually available for spawning at higher flows, and should be considered as an minimal indication of spawning habitat for rainbow trout. Brown trout typically spawn in the Fall, during low flow periods.

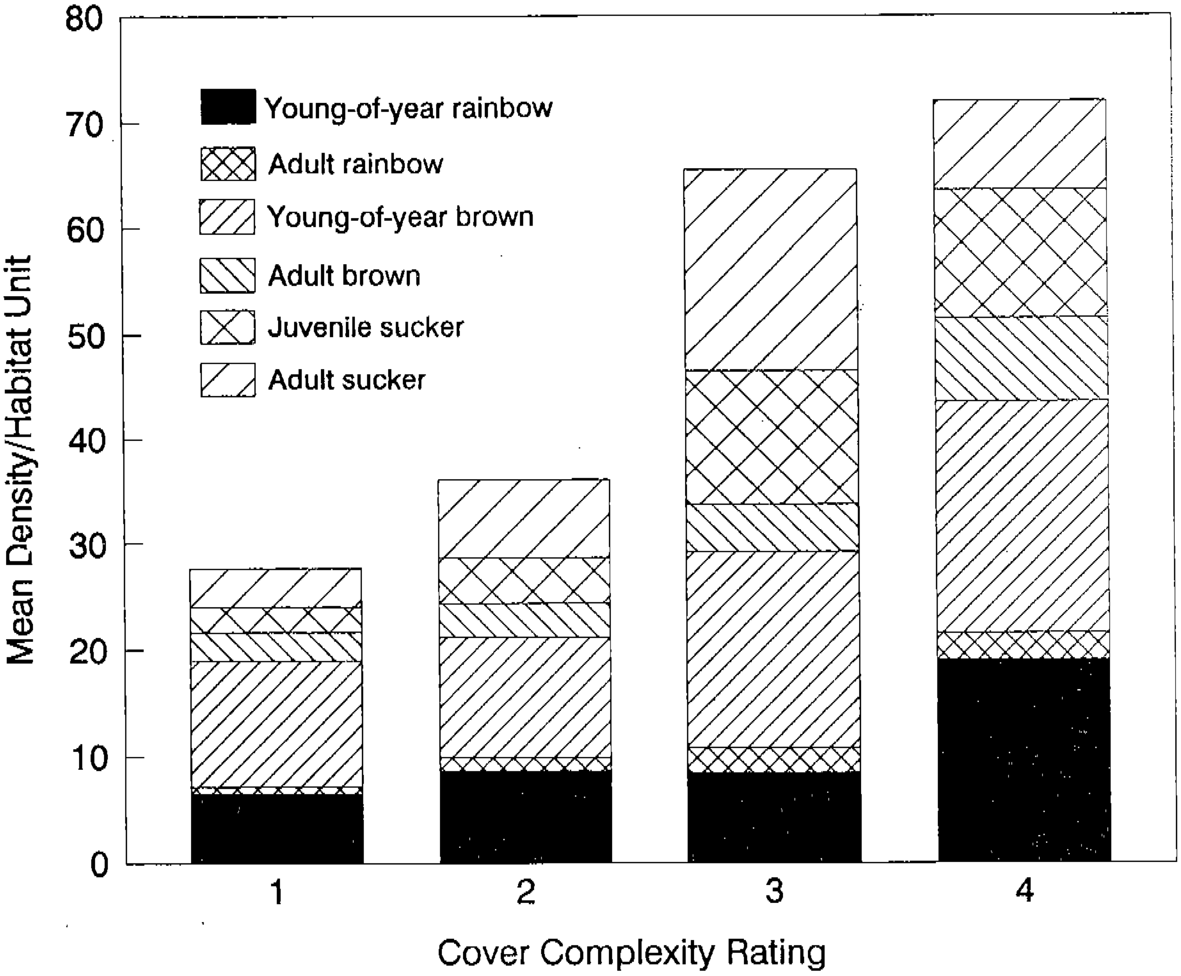

Figure 4. Relationship between cover complexity rating of Merced River main channel habitat types and mean number of fish per habitat type, for young-of-year or juvenile, and adult fish.

Streamside Vegetation

Plants typically encountered in the streamside zone were alder (Alnus sp.), azalea (Rhododendron sp.), milkweed (Asclepias sp.), currant (Ribes sp.), ferns (Pteridium sp.), willows (Salix sp.), horsetail (Equs sp.), sedges (Carex sp., Scirpus sp., etc.), ponderosa pine (Pinus ponderosa), sugarpine (Pinus lambertiana), lodgepole pine (Pinus murrayana), black oak (Quercus kelloggi), canyon live oak (Quercus chrysolepis), cottonwood (Populus sp.), bigleaf maple (Acer macrophyllum), mountain dogwood (Cornus nuttallii), incense cedar (Calocedrus decurrens), douglas fir (Pseudotsuga menziesii), sneezeweed, lupines (Lupinus sp.), and numerous grasses, flowers, forbs and other plants that we were unable to identify.

Exposed Banks and Access Points

From 273 main channel habitat units, an estimated 6,108 m of left bank (LB) were exposed within the study reach. For the right bank (RB), 212 units had 6,282 m of exposed banks. Assuming the length of the LB and RB study reach to be 15,722 m each, then 38.9% and 39.8% of the LB and RB were exposed, individually.

It should be noted that the presence of bare banks and headcut banks are not necessarily indicative of human-induced resource problems. Lateral channel cutting associated with stream meandering would cause bank degradation on the outside bend, and deposition on the inside of the meander. Evidence of historical channels were present in El Capitan Meadow, indicative of the migratory/meandering nature of streams in meadow/alluvial areas. In addition, certain channel types (e.g. C3) inherently exhibit unstable banks, owing to their associated landform and soil erosion characteristics. However, human influences appear to have accelerated and compounded these problems.

The exposed banks sustaining the greatest impacts were usually in association with public access points (parking areas, scenic vista points, foot and horse trails, etc) adjacent to trails, campground sites (Figure 5), and the housekeeping cabins (Figure 6). Although some of the exposed bank areas undergo cyclic periods of inundation and desiccation, and may otherwise have limited vegetation even under natural conditions, human impacts have prevented or severely limited the ability of grasses and other plants to become established in these streambank/riparian zones. Many of the sloughing banks were associated with access areas and horse trails. Erosion problems associated with horse trails were particularly noticeable upstream from the Pines campgrounds.

Headcutting and bank sloughing was observed in the meadows and other areas (Figures 7, 8). Some of the unstable areas were not in degradational zones, and overall, areas undergoing active erosion appeared to exceed areas of deposition. This was also noted by Madej et. al (1991). The factors responsible for many of the streambank problems were unclear to us. Due to the complicating human influences (bridges, rip-rapping, soil compaction, bare soils), the on-going fluvial processes were difficult to assess. These problems are best addressed by geo-morphic scientists; these topics were discussed in the report of Madej et al. (1991).

For the main channel, 172 habitat units had a total of 487 access points on the left bank, and 214 units had 646 access points on the right bank. The average number of access points (both banks) per meter increased from .056/m, above the Pohono Bridge area to .393/m near the Happy Isles gage station. These findings correspond with the higher level of human activity and land use patterns that exist in the upstream direction.

Figure 5. Left bank view of Pines Campground, downstream from Clark's Bridge. Soils are compacted, and the area is devoid of riparian vegetation.

Figure 6. Housekeeping Cabins area. Compacted soils, riparian vegetation consists only of trees.

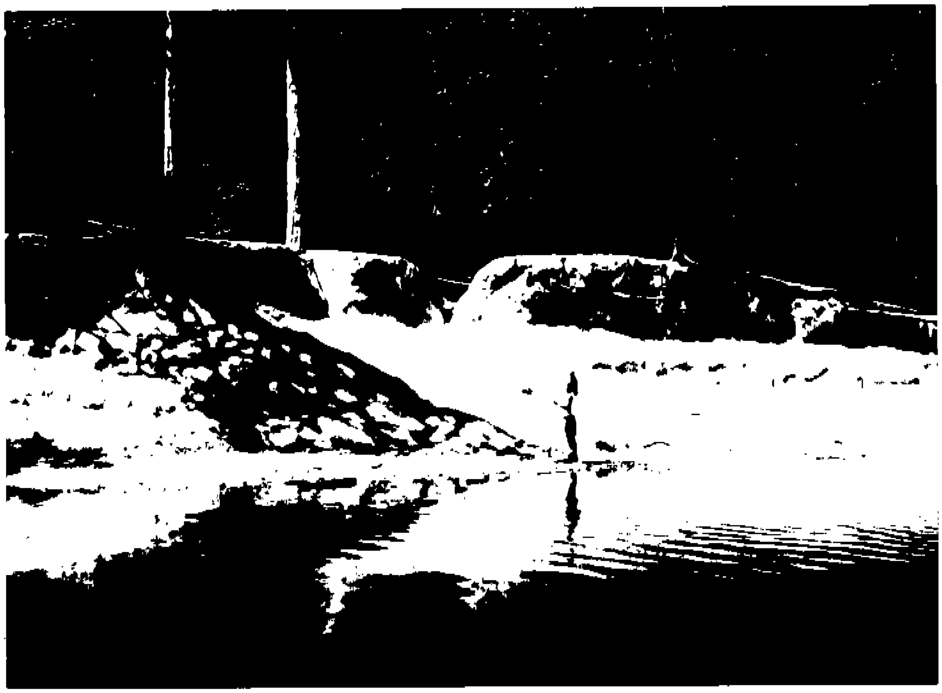

Figure 7. Streambank erosion, upstream from the Housekeeping area. Channel type C3.

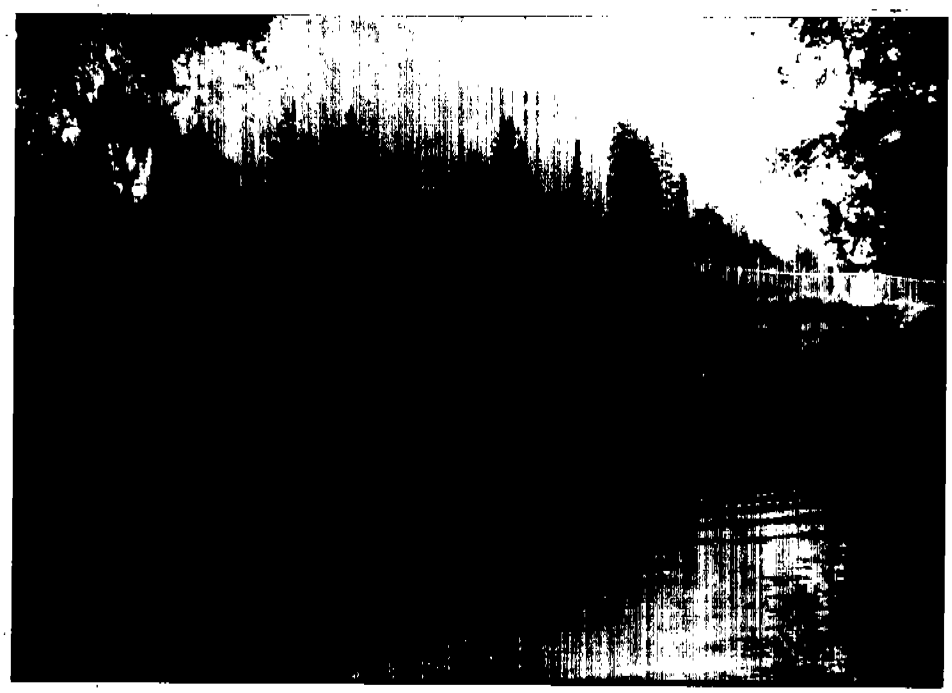

Figure 8. Streambank erosion, on left bank approximately 300 m downstream from the Chapel area.

RECOMMENDATIONS

The following recommendations are provided on the basis of managing the Merced River's aquatic resources to benefit the fishery. The recommendations are not intended to supplant existing management objectives or recommendations provided by other disciplines. We recommend and concur with the inter-disciplinary approach for the restoration of the Merced River, as discussed in the Restoration Strategy Workshop Proceedings (YNP, 1990, unpublished). In addition, although we have identified resource problems related to riverine geomorphological processes, we refer these technical solutions to persons with appropriate expertise.

Implementation of various restoration activities are expected to result in gradual but pronounced changes to the river channel and corridor. We assume that the physical restoration of the Merced River would also result in improved habitat conditions for the trout fishery. The fish populations may take years to benefit and attain stability from the restoration program.

We also recognize that the present restoration activities and implementation of the various recommendations will result in impacts and alteration of land-use patterns. As the Merced River is progressively allowed to undergo its natural riverine dynamics, processes such as channel meandering and seasonal flooding will undoubtedly result in conflicts with existing structures, roadways, and present land uses. Most of these impacts may be predicted, thereby allowing for advance modification of land uses and contingency planning.

STREAM CHANNEL AND BANK STABILIZATION

Flood Plain Management

When flows exceed the channel bankfull capacity, the excess volume of water spills into the flood plain. Flood plains represent a water storage area for flood events, an area of energy dissipation, and a sediment and nutrient deposition zone.

Cultural activities and structures within the Merced River flood plain have compromised their inherent natural values. For example, continual human disturbance and soil compaction along the Housekeeping and Riverside cabin areas have resulted in bare areas devoid of understory vegetation (Figure 6). Streamside vegetation serves to dissipate the energy of high flow events, traps sediments, provides shading, contributes organic litter, and promotes streambank stability.

Watershed and aquatic specialists have for decades advised managing the flood plain zone as an integral component of the aquatic ecosystem. Unfortunately, the various structures and campgrounds within the immediate Merced River flood plain are in conflict with this philosophy (Figures 5, 6). Relocation of these structures and land uses away from the flood plain would be an ideal remedy. An interim alternative could involve limiting or excluding access to the streambanks to initiate recovery. However, if total exclusion of the streamside and flood zones are not desirable, long-term rotational closures and usage of certain sites to promote recovery and minimize impacts may be a feasible alternative.

Bridge Structures

Several bridge structures span the Merced River, within the study reach. The bridge piers and abutments alter the flow patterns upstream and downstream of the structures, causing channel/bank scour and sediment deposition. The bridge crossing abutment areas are typically armored with rip-rapping to protect their integrity. The BSP habitats associated with bridges held high numbers of fish. These pools were the deepest habitats observed in the survey. The BSP habitats appear to have resulted from the presence of bridge structures, and thus are not entirely natural. Replacement of these structures with modern bridges may result in marked changes of the streambed, such as the filling in of the deep pools, thereby decreasing the depth. Although the streambed may return to a natural configuration, the loss of these deeply scoured pools may be inevitable. Despite this potential loss of habitat, the overall increase in the productivity of the stream from restoration efforts are expected to offset any actual loss of BSP habitat.

If replacement of the bridges is considered, modern structural designs that will minimize instream impacts are desired. The gravity of the problems posed by existing bridge structures, and geomorphologically compatible solutions are well documented in Madej et al. (1991).

Rip-Rap Removal and Instream Alterations

Extensive rip-rapping along the river banks act to stop or reduce degradational processes, but directs energy downstream, and also protects the immediate streambank from the shearing forces during high flow events. Rip-rapping has been placed along the streambanks in an effort to retard erosion of campsites, protect trees, horse trails, etc. Removal of the rip-rap would allow the stream to assume its natural hydraulic behavior.

Park visitors have modified the river channel in certain areas, particularly between the Lower Pines and Upper Pines campgrounds, by rocking the channel to facilitate their recreational activities (Figure 9). The modifications alter the natural fluvial arrangement of the stream, and dewater the margins of the channel. Aquatic insects would be affected by this dewatering. Although the exact impacts on the fisheries from these alterations are unknown, annual spring high flows should remove most traces of human alterations. However, considering the high level of visitor activity within the river, the indiscriminant alteration of the stream channel should be discouraged.

Woody Debris and Rock/Boulder Recruitment

Instream trees, root-wads, and branches are very effective in providing cover and shading for fish, protects fish from predation, and creates diverse habitats through flow deflection and scouring the stream bottom. Large tree trunks in the streambed also serve to accumulate gravel on their downstream side, thereby providing potential source of spawning gravel. Decaying woody debris is also a source of organic input into the aquatic system. We support the present policy of leaving large woody debris in the stream channel.

Major rockslides caused by seismic activity are a potential source of rock and boulder recruitment into the river channel. The YNP staff indicated that rockslides occur in the Three Brothers area and from Pohono to the El Portal areas. Since the placement of roads adjacent to these areas, the amount of fallen materials entering the stream channel (recruitment) has probably been reduced. In the event of rockslides onto these road surfaces, one action to consider would be to "push" these materials into the river channel, thereby mimicking the natural process.

Stream Access and Revegetation

Disturbed stream banks with compacted soils and trampled vegetation require exclusion from human disturbance, to re-establish vegetation. Resource area restrictions or closures are recommended. Severely affected streambank areas such as those adjacent to the Devil's Elbow Picnic Area may benefit from active intervention (where appropriate) such as manual tilling, recontouring

Figure 9. Right bank view of mid-channel alteration in the Pines Campground area. Rocks are funneling the flow down the center of channel.

Figure 10. Right bank of the Devil's Elbow parking area. The soils are compacted, with sloughing banks and unlimited visitor access to streambank areas.

the streambanks to 2:1 or 1.5:1 to allow better footing for revegetation efforts, planting and cuttings, and seeding with native legumes or grasses to promote rapid stabilization.

Limiting or closing access to disturbed sites is essential to prevent further degradation, and to promote rapid recovery of sites selected for revegetation efforts. If total access closures are not desirable to certain river areas, consider wooden walk-ways which would re-direct impacts away from disturbed areas. In areas with multiple access paths, reducing the number of undesirable access paths would be helpful. Identification of the main path through trail signs may help encourage proper usage. The Devil's Elbow parking area is another example of a heavily used area with compacted, crusty sandy soils and unlimited access to the streambank area (Figure 10).

Footpaths and horse trails paralleling the edge of the riverbanks pose a conflict with aquatic values. Some of the horse trails on the streambanks were protected with rip-rap. Relocation of these trails away from the streambank zone would promote the recovery of the riparian zone. If this is not possible, armoring the horse trail with small gravel would at least minimize surface erosion.

Water Diversion

A water intake pipe in the stream channel was observed just upstream of the Ahwahnee Bridge, on August 20. The intake pipe was mounted upon a large (about 2 m x 2 m) concrete slab. We could not determine whether the intake was screened. The pipe led to a large pump situated on the riverbank. The pump was in operation at the time of observation, and appeared to be the water source for the water sprinklers for the Ahwahnee Hotel lawn. The YNP plans to eliminate this diversion in the near future. In the interim, screening this intake structure would prevent entrainment of juvenile fish.

FISHERY MANAGEMENT AND EVALUATION

Instream Structures

Habitat improvement efforts using instream structures have gained tremendous popularity with the private and government professional fishery community. The FWS recognizes the value of well-planned, hydrologically compatible habitat structures in certain fisheries habitat improvement applications. However, the FWS believes that instream structures are not an appropriate consideration for the Merced River. The FWS supports the philosophy of addressing the factors directly responsible for habitat degradation rather than cosmetic, symptomatic treatment and mitigation of the river's physical and biological problems. The benefits realized, even from an intensive instream structure placement program probably may not be significant when compared to the benefits already accruing from current practices such as leaving woody debris in the stream channel. Other on-going and future restoration measures such as rip-rap removal, re-stabilization and revegetation of disturbed banks hold considerable promise in improving natural streambank stability and resistance to further erosion. Also, these measures are more compatible with YNP restoration mandates.

Sport Fishing Regulations

The YNP in cooperation with CDFG has recommended a catch and release fishery regulation for rainbow trout, and a five fish bag limit for brown trout, within the valley floor area (from Pohono Bridge to the Happy Isles Footbridge). The recommendation also identified the use of barbless, artificial flies and lures only. Use of artificial lures and flies are known to result in a lower post-release mortality of fish than when using bait. This regulation appears biologically sound, since the intense angling pressure within the valley floor probably contributes to the low abundance of rainbow trout. The high fishing pressure was indirectly evidenced by angling line, bait containers, lures, bobbers, and other lost or discarded paraphernalia throughout the study area.

In order to evaluate the effects of restoration activities, and the status of the fisheries, periodic monitoring and evaluation is recommended. Monitoring could include electro-fishing surveys, direct observations, benthic surveys, and "redy-mapping". With the adoption of the species specific harvest regulation for the greater valley floor, the need for a fishery creel census would be a high priority in 1992 and 1993. The creel census will be helpful to determine whether rainbow trout populations will benefit from the change in fishing regulations. The census and recommended monitoring efforts would be dependent on attaining funding sources to enable their initiation.

In order to promote organized and coordinated fishery efforts within YNP, the cooperation of the involved agencies is needed to maximize efficiency, prevent work overlap, and design monitoring projects which result in compatible information.

Electro-fishing Surveys and Direct Observation

The CDFG has conducted electro-fishing surveys of the Merced River during 1990 and 1991. The electro-fishing surveys provide empirical evaluation of species composition, abundance, age structure, and production. Continuing these surveys in selected areas of the Merced River within the valley floor is recommended. The electro-fishing would also allow calibration of the direct observation snorkeling work; this would allow greater reliance and opportunities to utilize direct observation methods, and thereby realize a greater cost-savings over the long-term. A significant opportunity exists for the CDFG and FWS to coordinate together on these fisheries efforts, and acquire valuable management information.

The direct observation work indicates that the BSP and other deep pool habitats supports relatively substantial numbers of fish. The feasibility and need for a boat-shocker to sample the deeper pools could be explored amongst the YNP, CDFG, and FWS staff. Although river access to launch a conventional vessel might be limited, perhaps an inflatable unit could be deployed.

However, underwater observation work provides good indication of abundance in deeper water that is presently not sampled by backpack electro-fishing. The snorkeling work can usually be accomplished by a two or three-person crew. Tentatively, we recommend that the selected (index) areas be snorkeled annually; these areas would be associated with on-going restoration projects. Intensive observations could be conducted annually, whereby selected reaches throughout the present study area (from Pohono Bridge to the Happy Isles Gage Station) would be snorkeled.

At present, CDFG and FWS fish sampling and observations have taken place during the seasonal low flow periods; this work provides information on fish distribution and habitat usage during a period of time that is thought to be the most demanding on the fish populations.

Habitat Typing and "Redy-Mapping"

Monitoring for changes in the stream and immediate stream bank zones would be done throughout the life of the restoration projects. We anticipate significant changes in the stream channel and riparian zones as a result of present and future restoration activities. Tentatively, we recommend that the present study area be habitat-typed again in four to five years. Repeating the reach-wide typing is necessary for up-dating the initial survey, and to document and assess changes in the total study reach that have occurred since the initial survey.

The monitoring of index study sites will allow for site-specific scrutiny of areas identified for or undergoing current restoration work. These index sites are chosen within logical categorical divisions within the stream, such as distinct channel types. The index sites allows for drawing inferences on the larger sub-reach (channel type) of stream that the index site represents. Habitat typing and direct observations may be performed on these index areas to monitor site specific conditions related to restoration activities.

The FWS is planning to conduct "redy-mapping" work on selected areas of the Merced River. The river channel will be mapped to scale to serve as a baseline reference to document and monitor physical, and biological habitat changes over time. Riverbank areas with on-going restoration activities, such as the dump site removal (near the El Capitan picnic area) can be mapped for monitoring purposes. The mapping documentation ("redy-mapping") of areas undergoing restoration habitats could be performed bi-annually; this level of monitoring will track subtle and major changes in vegetation, stream meandering and habitat recovery.

Mainstem and Tributary Spawning Surveys

Quantifying the number of trout spawning in the mainstem and tributary spawning areas is another way of evaluating the resource and gaging the success of restoration activities. Over the long-term, restoration efforts are expected to reduce sediment levels in the stream substrate, and this should translate to a greater quantity and quality of spawning gravels available for trout. An increase in the number of adult spawners would be expected.

The tributary streams to the Merced within the valley floor are probably providing significant spawning and rearing habitats for salmonids. Both adult and juvenile salmonids were observed in Tenaya Creek and Yosemite Creek. Salmonids probably utilize other tributary streams such as Bridalveil Creek, Ribbon Creek, and Illilouette Creek.

Considering the level of human activities within the valley floor, the status of the tributary fisheries need to be determined. Spawning and habitat surveys would identify what species are present, the amount and distribution of available spawning, rearing and adult habitats, and existing or potential habitat problems. This work would be conducted visually, within segments of the stream that are accessible for salmonid migration, from the tributary confluence to upstream areas. The primary objective in the tributaries is to determine if salmonids from the mainstem Merced River are spawning in the tributary streams. If so, special management considerations may be needed for these tributaries.

Preliminary efforts would focus on the largest tributaries; spring surveys for adult rainbow trout spawners, and fall surveys for adult brown trout.

Benthic Sampling

Macroinvertebrate sampling of the stream's benthic community would provide direct indication of the health of the aquatic system. Traditional macroinvertebrate analysis designs often require substantial numbers of samples to be taken, both spatially and temporally.

Winget and Mangum (1979) have developed a macroinvertebrate analysis methodology that evaluates the condition of a stream in relation to its own biological potential (biotic condition index). The biotic condition index evaluates the condition of a stream based on its water chemistry and the presence or absence of various aquatic taxa that are tolerant or intolerant ("niche width") to environmental stressors. This methodology is generally independent and less sensitive to the sample size collected, and therefore does not require large sample sizes common to other methods.

Benthic sampling of the index areas would be the logical sites to initiate this work. Control or comparison sites could be selected in similar habitat/substrate areas where restoration activities are not taking place. The YNP staff in cooperation with the U.S. Geological Survey is developing a 3-year aquatic invertebrate monitoring protocol for the Merced River Restoration program.

Temperature Monitoring

During our 1991 surveys, we noted daytime maximum surface water temperatures in excess of 21°C (70°F) for the Merced River. Although these temperatures do not approach lethal levels for resident salmonids, sustained elevated temperature conditions constitute a physiological stress. Several questions arose during the course of our 1991 work: is thermal stratification occurring in the larger, deeper pools? Are cool-water seeps limited to adjacent springs, and seeps in meadow pool habitats? We noted localized "micro-pockets" of cooler water on the stream bottom, in the meadow areas; in some areas we observed brown trout lying over these seeps. Placement of recorder thermographs in selected locations would provide valuable information. A thermograph could be placed downstream from the Happy Isles area, and additional units in downstream pools.

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PERSONAL COMMUNICATION

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Appendix A: Channel classification as described by Rosgen 1985.

Stream Type	Gradient (%)	Dominant Partical Size of Channel Materials	Channel Entrenchment Valley Confinment
A1	4-10	Bedrock	Very deep; very well confined
A1-a	10+	Same as A1	
A2	4-10	Large & small boulders w/mixed cobbles	Same as A1
A2-a	10+	Same as A2	
A3	4-10	Small boulders, cobbles, coarse gravels, some sand.	Same as A1
A3-a	10+	Same as A3	
A4	4-10	Predominantly gravel, sand, and some silts.	Same as A1
A4-a	10+	Same as A4	
A5	4-10	Silt and/or clay bed and bank materials.	Same as A1
A5-a	10+	Same as A5	

Stream Type	Gradient (%)	Dominant Partical Size of Channel Materials	Channel Entrenchment and Valley Confinement
B1-1	1.5-4.0	Bedrock bed:banks are cobble, gravel, some sand.	Shallow entrenchment; moderate confinment
B1	2.5-4.0 (X=3.5)	Predominately small boulders and very large cobble.	Moderate entrenchment; moderate confinment
B2	1.5-2.5 (X=2.0)	Large cobble mixed w/small boulders and coarse gravels	Moderate entrenchment; moderate confinment
B3	1.5-4.0 (X=2.5)	Cobble bed w/mixture of gravel and sand. Some small boulders	Moderate entrenchment; well confined
B4	1.5-4.0 (X=2.0)	Very coarse gravel w/cobbles, sand and finer materials	Deeply entrenched; well
B5	1.5-4.0 (X=2.5)	Silt / clay	Deeply entrenched; well confined.
B6	1.5-4.0	Gravel w/few cobbles and w/noncohsive sand and finer soil.	Deeply entrenched; slightly confined

Stream type	Gradient (%)	Dominant Particale Size of Channel Materials	Channel Entrenchment Valley Confinment
C1-1	1.5 or less (X=1.0)	Bedrock bed, gravel sand or finer banks.	Shallow entren-chment; partially confined.
C1	1.0-1.5 (X= 1.3)	Cobble, coarse gravel bed, gravel, sand banks.	Moderate entren-chment; well confined.
C2	0.3-1.0 (X=0.6)	Large cobble bed w/mixture of small boulders and coarse gravel.	Moderate entren-chment; well confined.
C3	0.5-1.0 (X=0.8)	Gravelbed w/mixture of small cobble and sand.	Moderate entren-chment; slightly confined.
C4	0.1-0.5 (X=0.3)	Sandbed w/mixture of gravel and silt. No bed armor.	Moderate entren-chment; slightly confined.
C5	0.1 or less (X=0.05)	Silt clay w/mixture of medium to fine sand, no bed armor.	Moderate entren-chment; slightly confined.
C6	0.1 or less (X=0.05))	Sandbed w/mixture of silt and some gravel.	Deeply entrenched; unconfined.

Stream Type	Gradient (%)	Dominant Particle Size of Channel Materials	Channel Entrenchment Valley Confinement
D1	1.0 or greater (X=2.5)	Cobble bed w/mixture of coarse gravel, sand, and small boulders.	Slightly entrenched; no confinement.
D2	1.0 or less (X=1.0)	Sandbed w/mixture of small to medium gravel and silt.	Slightly entrenched; no confinement.
F1	1.0 or less	Bedrock bed w/few boulders, cobble and gravel.	Total confinement.
F3	1.0 or less	Cobble/gravel bed with locations of sand in depositional sites.	Same as F1
F4	1.0 or less	Sand bed with smaller amounts of silt and gravel.	Same as F1
F5	1.0 or less	Silt/clay bed and banks with smaller amounts of sand.	Same as F1

APPENDIX B: List of Habitat Type Codes

Habitat No.	Code	Habitat Type Description
1	LGR	Low Gradient Riffle
2	HGR	High Gradient Riffle
3	CAS	Cascade
4	SCP	Secondary Channel Pool
5	BWP-bo	Backwater Pool (boulder formed)
6	BWP-rtwd	Backwater Pool (rootwad formed)
7	BWP-log	Backwater Pool (log formed)
8	TRC	Trench/Chute
9	PLP	Plunge Pool
10	LSP-log	Lateral Scour Pool (log formed)
11	LSP-rtwd	Lateral Scour Pool (rootwad formed)
12	LSP-bdrk	Lateral Scour Pool (bedrock formed)
13	DPL	Dammed Pool
14	GLD	Glides
15	RUN	Run
16	SRN	Step Run
17	MCP	Mid-Channel Pool
18	EGW	Edgewater
19	CCP	Channel Confluence Pool
20	LSP-bo	Later Scour Pool (boulder formed)
21	POW	Pocket Water
22	CRP	Corner Pool
23	STP	Step Pool
24	BRS	Bedrock Sheet
25	BSP	Bridge Scour Pool

APPENDIX C: Channel Type Sequence of the Merced River

B2 Start: Pohono Bridge
End: Bridalveil Meadow Parking Area ("Valley View")

Features: Lower Bridalveil Meadow.

C2 Start: Bridalveil Meadow Parking Area ("Valley View")
End: Start of Bridalveil Moraine

Features: Bridalveil Creek

B2 Start: Start of Bridalveil Moraine
End: Beginning of El Capitan Meadow

C4 Start: Beginning of El Capitan Meadow
End: Slightly upstream of Three Brothers Vista.

Features: El Capitan Bridge, Cathedral Spires Vista Parking, Devil's Elbow, Cathedral Beach,

C3 Start: Slightly upstream of Three Brothers Vista
End: Rocky Point, slightly upstream from transmission line corridor.

Features: Eagle Creek confluence

C4 Start: Rocky Point, slightly upstream from transmission line corridor.
End: Swinging Bridge

Features: Sentinel Beach, Leidig Meadow.

C3 Start: Swinging Bridge.
End: Slightly downstream of Sugarpine Bridge.

Features: Island, Yosemite Creek, footbridge, Sentinel Bridge, Housekeeping area, footbridge to Lower River campground, Stoneman Bridge, Ahwahnee Bridge.

C2 Start: Slightlyly downstream of Sugarpine Bridge.
End: Upstream of Medial Moraine (adjacent to Upper Pines Campground).

Features: Tenaya Creek confluence, North Pines and Lower Pines campgrounds, Clark's Bridge.

B2 Start: Upstream of Medial Moraine.
End: Happy Isles Gaging Station.

Features: Happy Isles Bridge, Happy Isles Gage Bridge.