Summary of fall-run chinook salmon and steelhead trout spawning in the lower Mokelumne River, California 1996-2003

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Abstract – Annual fall-run chinook salmon redd counts during the period 1996-2003 ranged from 627 in 1999 to 1,325 in 1997. During the same period, steelhead trout redd counts ranged from 0 in 1996 and 1997 (years when high flows precluded river access and visibility) to 50 in 2002. Since 1996, superimposition levels have trended downward (17% in 1996 and 8.5% in 2002), while the amount of rehabilitated and additional spawning habitat has increased (approximately 21,483 tons of gravel added over 8 years). While total escapement of fall-run chinook salmon has been well above the 3,921 long-term average during the 1996-2003 period, changes in the structure and operation of the Mokelumne River Fish Hatchery ladder have resulted in an increased percentage of the run entering the hatchery. Consequentially, the amount of naturally spawning salmon has not increased at the same rate as the increase in total escapement.

INTRODUCTION

Since 1990 East Bay Municipal Utility District (EBMUD) biologist have been conducting annual salmonid spawning surveys on the lower Mokelumne River. The surveys are designed to enumerate redds and collect associated environmental and/or physical data. This report will cover results of annual salmonid spawning surveys from 1996-2003. Specifically, spawning timing, duration and number of redds will be covered. Additionally, other factors associated with spawning will be covered including superimposition, use of enhancement gravels, environmental data, and fish density interactions.

SITE

The lower Mokelumne River is an approximately 54-km reach of regulated stream between Camanche Dam, the downstream-most non-passable barrier to anadromous fish, and its confluence with the Sacramento-San Joaquin Delta. The river between Camanche Dam and Lake Lodi, a seasonal reservoir with a fish passage facility at Woodbridge Irrigation District Dam (WIDD), is characterized by alternating bar complex and flatwater habitats with a gradient of 0.0017.

At least 35 fish species occur in the LMR including prickly sculpin *Cottus asper*, Sacramento sucker *Catostomus occidentalis*, and two anadromous salmonids, steelhead *O. mykiss,* and fall-run chinook salmon. Both salmonid populations are supplemented by fish reared in the Mokelumne River Fish Hatchery or imported from the Feather River and Nimbus hatcheries (American River). Abundant non-native fish species include western mosquitofish *Gambusia affinis*, golden shiner *Notemigonus crysoleucas*, and spotted bass *Micropterus punctulatus*.

METHODS

From 1990-2003, annual salmonid spawning surveys were conducted in the lower Mokelumne River. This report will only detail results from 1996-2003. The annual survey periods varied because of variations in flows (safety and visibility issues during high flows), but generally began in September and ended in March (Table 1). From September – December surveys were conducted weekly, with bi-weekly surveys for the remainder of the season. The reach surveyed was from the base of Camanche Dam to

Elliott Road, approximately 16 km. Surveys consisted of three individuals walking abreast down the river (water depths to 1.2 m) and searching for signs of redd construction. This method has been used in past Mokelumne River spawning surveys and in other rivers and streams. Redd locations were recorded using a hand-held Global Positioning System (GPS) unit (Trimble Pro XR) and a laser range finder (Atlanta Advantage). Location of each redd was downloaded from the GPS unit into an ArcView (ESRI) coverage. In addition to being mapped, individual redds were marked with a 115-mm brightly colored plastic tag (different colors used each year). Tags were numbered and anchored to the substrate at the peak of each redd tailspill with a 216mm steel bolt with a 40 mm drywall toggle wing anchor to differentiate old redds from new during subsequent surveys and monitor scour of individual redds. Tags were recovered the first week of the following annual redd survey.

In addition to redd locations, notations were made regarding the associated characteristics. Additional measurements included cover type and numbers of fish associated with each redd. Types of cover included overhanging vegetation, canopy, turbulence, boulders, submerged vegetation, large woody debris, artificial structure, and undercut banks. Cover was judged to be associated with individual redds when it was directly adjacent to or within an approximate 5 meter radius. An assumption was made that cover within 5 meters was available for use by individual fish. Overhanging vegetation was considered to be any material from the water surface to approximately 5 meters, while canopy was any vegetation >5 meters in height.

In order to determine spawning density within the river, escapement estimates were used. EBMUD conducts an annual monitoring program at WIDD in Lodi, CA, which is approximately 23-km downstream of the monitored spawning reach. The facility includes a multiple stage fishway with video cameras installed in both the high and low stage ladders. A majority of the fish ascending the fishways are counted and sexed. Results from the monitoring at WIDD are used to estimate escapement to the Mokelumne River. The Mokelumne River Fish hatchery (MRFH) is operated by CDFG. The hatchery conducts annual spawning and rearing of fall-run chinook salmon and steelhead trout. CDFG staff collects information on numbers and sex of salmon entering the facility. The difference between the WID and MRFH counts are used to estimate the in-river spawning population numbers and sex composition.

Data analysis was performed using ArcMAP, Arc/Info (ESRI) systems and EBMUD LMR GIS. The lower river GIS is based on two data sets: regional USGS maps with a 1:24,000 scale and local maps based on orthorectified photos (taken February 28, 1994, at a release of 202cfs from Camanche Dam) with a 1:4,800 scale.

RESULTS

Redd Numbers and Distribution

The number of Chinook salmon redds has varied from a high of 1,325 in 1997 to a low of 627 in 1999 (Figure 1). Prior to 1996, redd numbers had been as low as 71 in 1990. A comprehensive summary of escapement, hatchery returns, and redd numbers from 1990-2003 is contained in Table 2.

Redd distribution between Reach 5 and 6 has been fairly consistent since 1996. The percentage of spawning occurring in Reach 6 ranged from 79.5 to 86.5%, while percentages in Reach 5 ranged from 13.5 to 20.5% (Table 3). Sporadic spawning has been observed and recorded in areas outside of Reach 5 and 6. Pockets of sub-optimal spawning habitat are associated with bridge abutments, levee repairs, and other structures.

O. mykiss spawning totals for the 1996-2003 period are summarized in Figure 2. Numbers have ranged from 9 in 1998 to 50 in 2002. There are a number of difficulties enumerating *O. mykiss* redds. Since the management of *O. mykiss* in the Mokelumne River is focused on anadromous forms, our survey efforts are focused on steelhead trout. Unless the fish is observed on a redd it is difficult to determine if it was built by an anadromous or resident *O. mykiss*. Flows can also impact the survey season. In 1996 and 1997 surveys were curtailed due to high flows and reduced visibilities. Peak spawning season for steelhead is from mid-January to mid-February (Figure 3). Nearly all of the steelhead redds observed in the 1996-2003 period were located in Reach 6.

Superimposition

The level of chinook salmon redd superimposition has been trending downward and ranged from 17% in 1996 to 8.5% in 2002 (Figure 4). Gravel enhancement projects, discussed in the following section, have increased the amount of spawning habitat in the river. Since 1996 there has been only two instances of *O. mykiss* redd superimposition. In both instances the redd affected was from a chinook salmon.

Enhancement Gravel Usage

Enhancement projects in the lower Mokelumne River are of two types: rehabilitation and restoration. Rehabilitation projects target existing sites with gravel addition and reshaping of contours. Rehabilitation sites may have supported spawning in prior pre-project years. Restoration projects are targeted at areas where no spawning had been recorded subsequent to 1990. Since 1990, 14 enhancement projects have been completed in the lower Mokelumne River. From 1996 to 2003, enhancement gravels have accounted for 30.5 to 48.7% of the total redds (Figure 5). Figure 6 depicts use of individual enhancement sites since 1996. Note the differences between rehabilitation sites versus restoration sites.

Environmental Conditions

Minimum, maximum, and average water temperatures for spawning and incubation periods (October 1-April 30) from 1996-2003 are summarized in Figure 7. The highest maximum daily temperature recorded during any spawning or incubation period from 1996-2004 was 16.6°C, while the highest average temperature for a spawning/incubation period was 12.9°C.

Flow data (minimum, maximum, and average Camanche releases) for spawning and incubation periods from 1996-2003 are summarized in Figure 8. The lowest daily release during the 1996-2004 seasons was 223cfs, while the highest release was 5,190cfs. Average daily flows during the same period ranged from 256cfs to 2,048cfs. Consecutive above average precipitation years from 1996-1998 resulted in flood flow releases.

DISCUSSION

Annual chinook salmon returns to the lower Mokelumne River from 1996-2003 have exceeded the long-term (1940-2003) average of 3,921. These large escapements have resulted in an average yearly redd count of 979 for the 1996-2003 period. For comparison, in 1990-1995 the long-term escapement average was achieved only two out of the six years and the average yearly redd count was 455. Although spawning periods from 1996-2003 included JSA water year types from dry to wet, releases were consistent enough during those years that there were no recorded incidents of redds being dewatered.

During the period 1996-2003 two major factors influenced salmonid spawning patterns in the lower Mokelumne River. The expansion of the enhancement program and its focus on the uppermost spawning area increased the amount and quality of spawning habitat. Since 1996 approximately 21,483 tons of gravel has been placed in nine sites within the Mokelumne River. Of these sites, two had not previously contained any suitable spawning habitat. The end result of the enhancement program is an increase in both spawning habitat quantity and quality. These results are indicated, in part, by the downward trend in redd superimposition.

The second factor influencing salmonid spawning patterns is related to improvements made to the Mokelumne River Fish Hatchery ladder. From 1990-1999 the percentage of the total chinook salmon escapement returning to the hatchery was approximately 46%. Prior to the Fall 2000 spawning season, CDFG made improvements to the entryway of

the ladder leading into the MRFH. Since Fall 2000, the percentage of the total chinook escapement returning to the hatchery has been approximately 75%. The increase in hatchery returns, relative to total escapement, resulted in decreased in-river spawning. As an example, the escapement total for 1997 was 10,163, and in 2003 the total was 10,238 (Table 2). The corresponding redd counts for the years 1997 and 2003 were 1,325 and 807 respectively, a difference of over 500 redds. Although the totality of the difference cannot be entirely attributed to the increased hatchery escapement, it appears to be having an effect on the number of in-river spawners.

While the spawning gravel enhancement program has resulted in an increase in spawning habitat quality and quantity, unrelated increases in aquatic macrophytes appears to have negatively impacted some of the spawning sites directly downstream of Camanche Dam. The 2002 spawning report documented reductions in the number of redds at some of these sites. In Spring 2003 increased releases flushed vegetation from the affected sites, resulting in an increase in the number of redds observed during the Fall/Winter 2004 (Figure 6).

Run composition (the sex ratio and grilse component of the spawning population) is a factor that can influence the number of redds and superimposition levels within the Mokelumne River. The number of redds within the river is a function of the number of females, since salmonid redds are constructed by the female. For instance, in-river escapement estimates for 1995 and 1999 were 2,094 and 2,185 respectively. However, the estimated in-river adult female counts were 1,213 in 1995 and 568 in 1999. The

effects of these differences can be seen in the redd counts, where there were 261 more redds in 1995 compared to 1999 (Table 2). Grilse are generally not involved in redd construction and are satellite spawners. Consequently, the number of grilse contribute to the total escapement, but very little to the redd count. Finally, run timing can also influence the redd distribution and superimposition levels. When the run is protracted and spread over a greater number of weeks, as in 1998, the incidence of superimposition can be higher, whereas in shorter abrupt runs the superimposition levels can be lower, as observed in 2002 (Figures 1 and 4). When the bulk of the salmon escapement occurs within a short amount of time the adult fish are all on the spawning grounds simultaneously and are able to defend their individual territory. In a more protracted run adults come on to the spawning ground over time and early arriving fish are not there to defend territories.

Since 1996 chinook salmon escapement has increased and remained well above the long-term historical average. Concurrently, in-river escapement numbers and redd counts have increased during the 1996-2003 period. The increase and rehabilitation of spawning habitat within the lower Mokelumne River has provided a net benefit as indicated, in part, by decreased superimposition. Based on the decreased incidence of superimposition and ongoing habitat enhancement projects, it is likely that the river could support increased numbers of spawners and associated redds. By working cooperatively with CDFG and their management of the ladder operations at the MRFH, natural production of chinook salmon can be increased within the lower Mokelumne River while maintaining hatchery production goals.

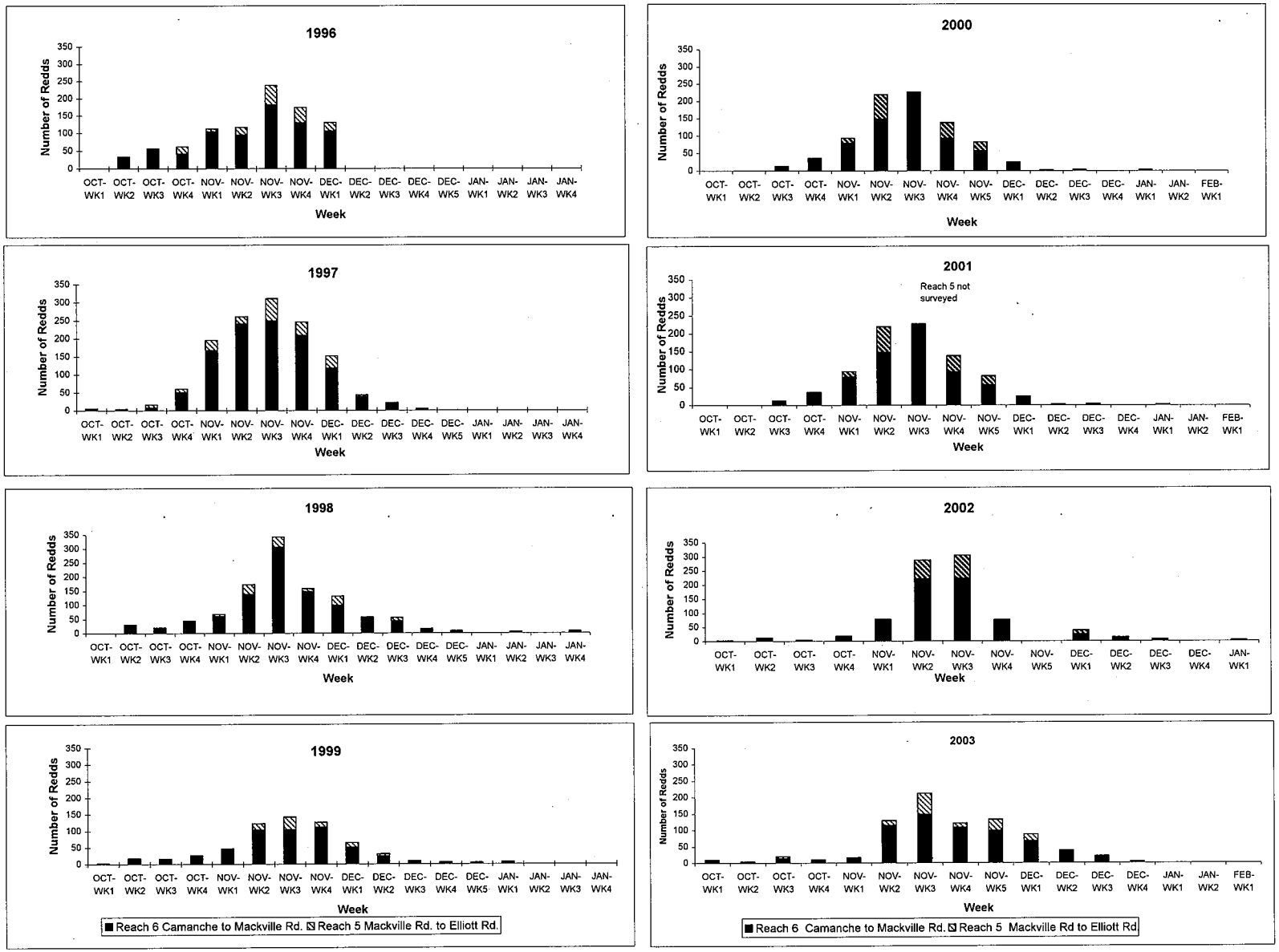

Figure 1. Number and distribution (temporal and spatial) of chinook salmon redds in the lower Mokelumne River, California from 1996-2003.

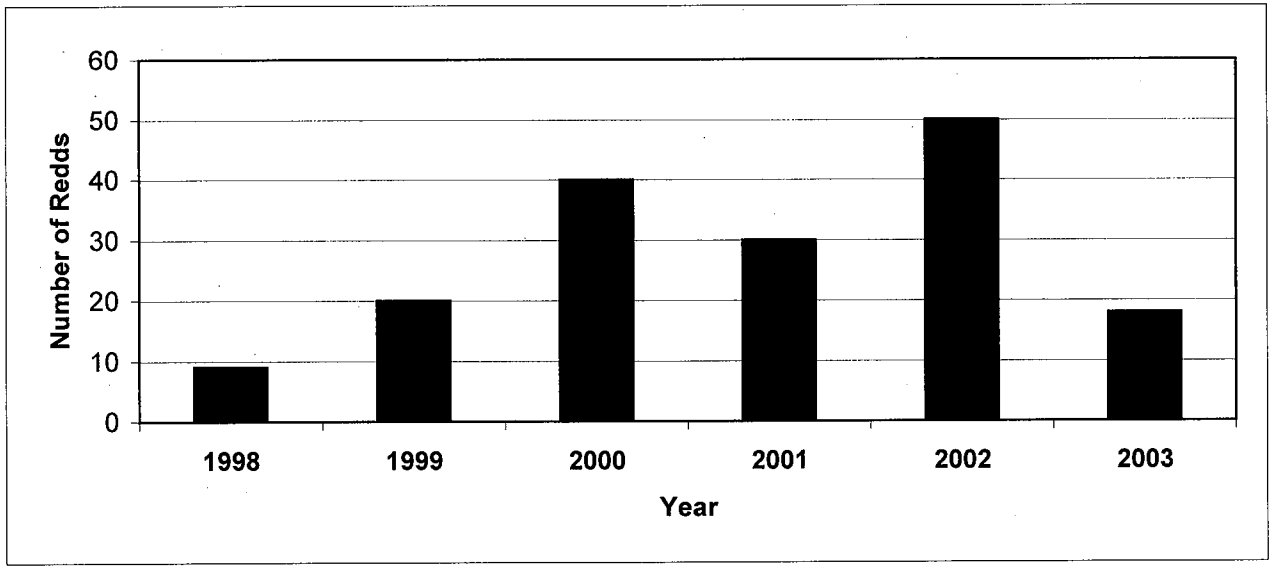

Figure 2. Steelhead *O. mykiss* redds in lower Mokelumne River, California 1998-2003.

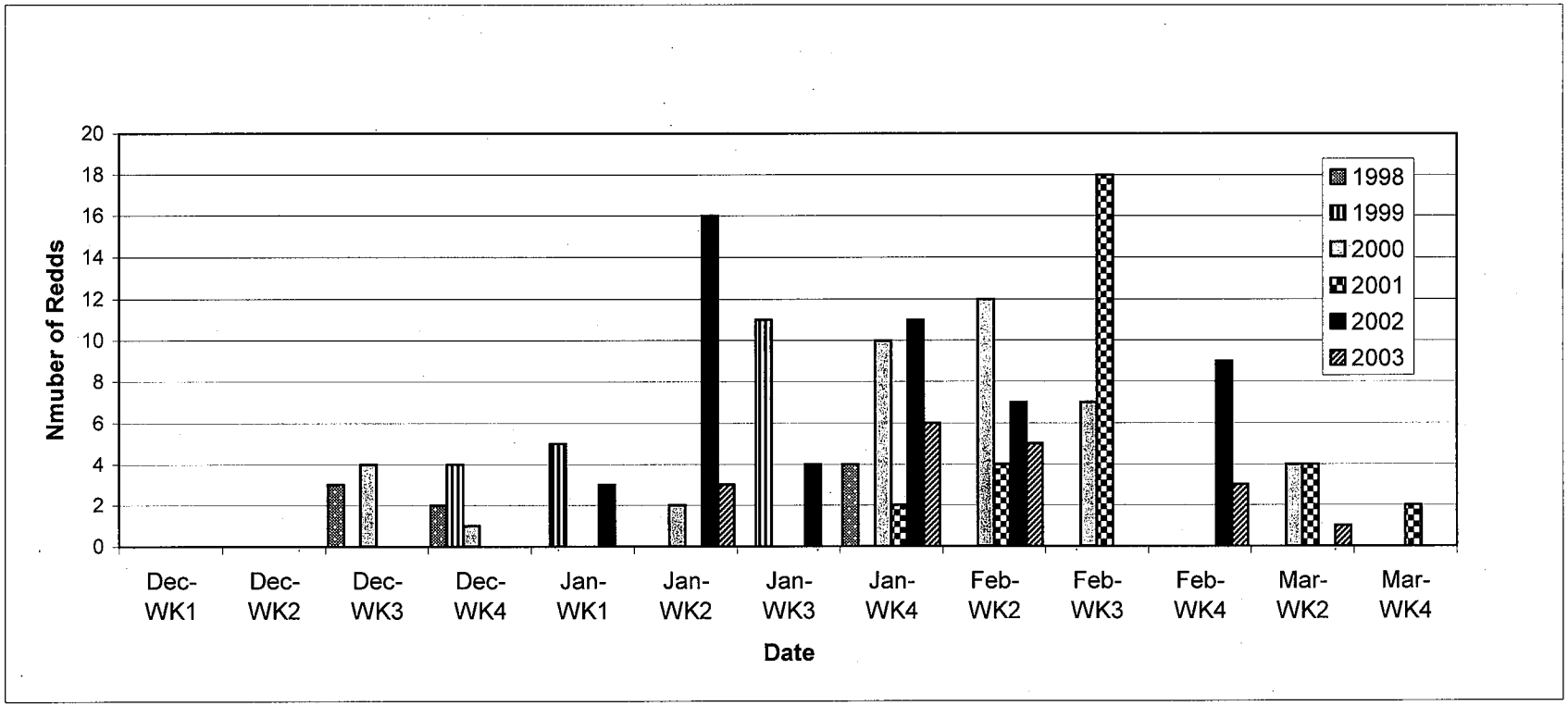

Figure 3. Temporal distribution of steelhead *O. mykiss* redds in the lower Mokelumne River, California 1998-2003.

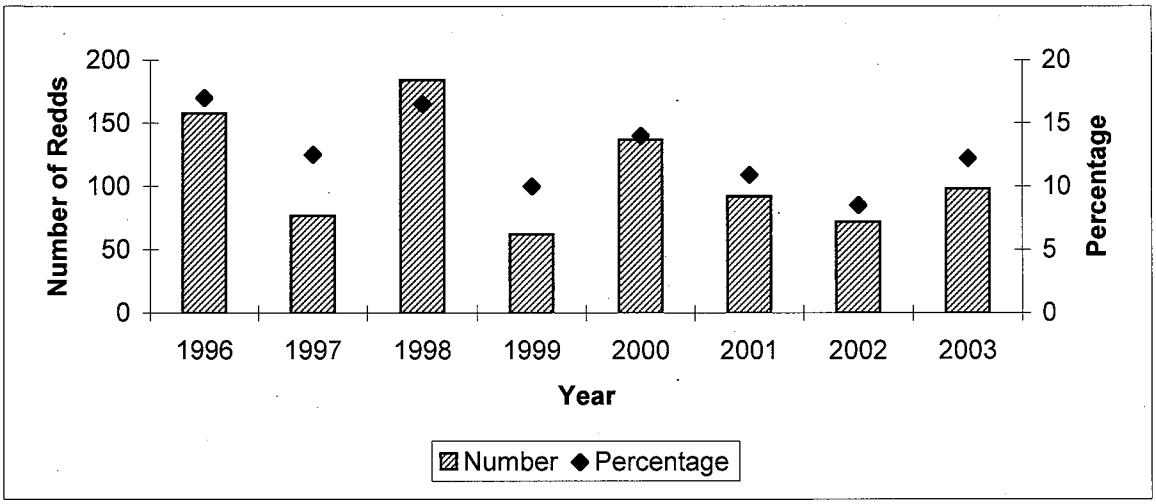

Figure 4. Number and percentage of total chinook salmon redds superimposed on in the lower Mokelumne River, California 1996-2003.

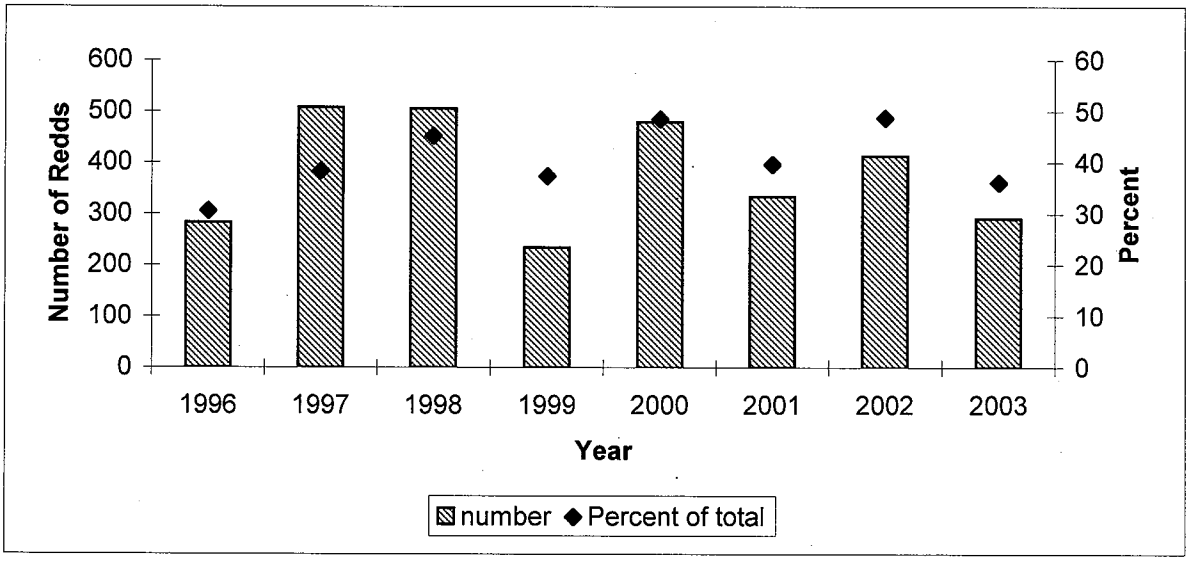

Figure 5. Number of redds and percentage of total redds constructed in enhanced areas of lower Mokelumne River, California 1996-2003.

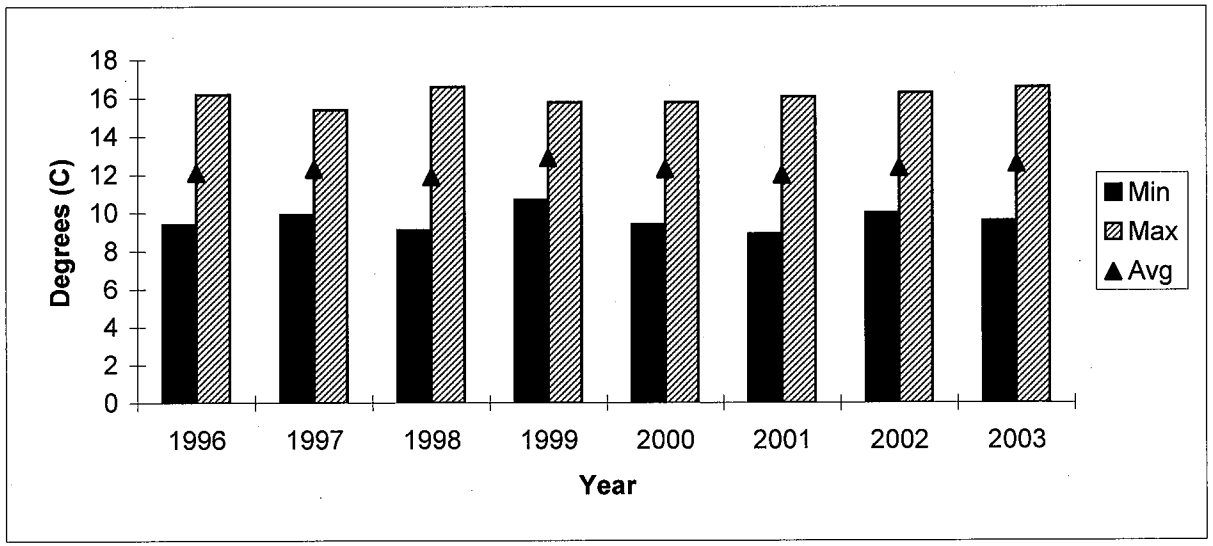

Figure 6. Minimum, maximum and average water temperature at the Mokelumne River Dayuse Area during spawning and incubation period (October-April) for the 1996-2003 spawning seasons.

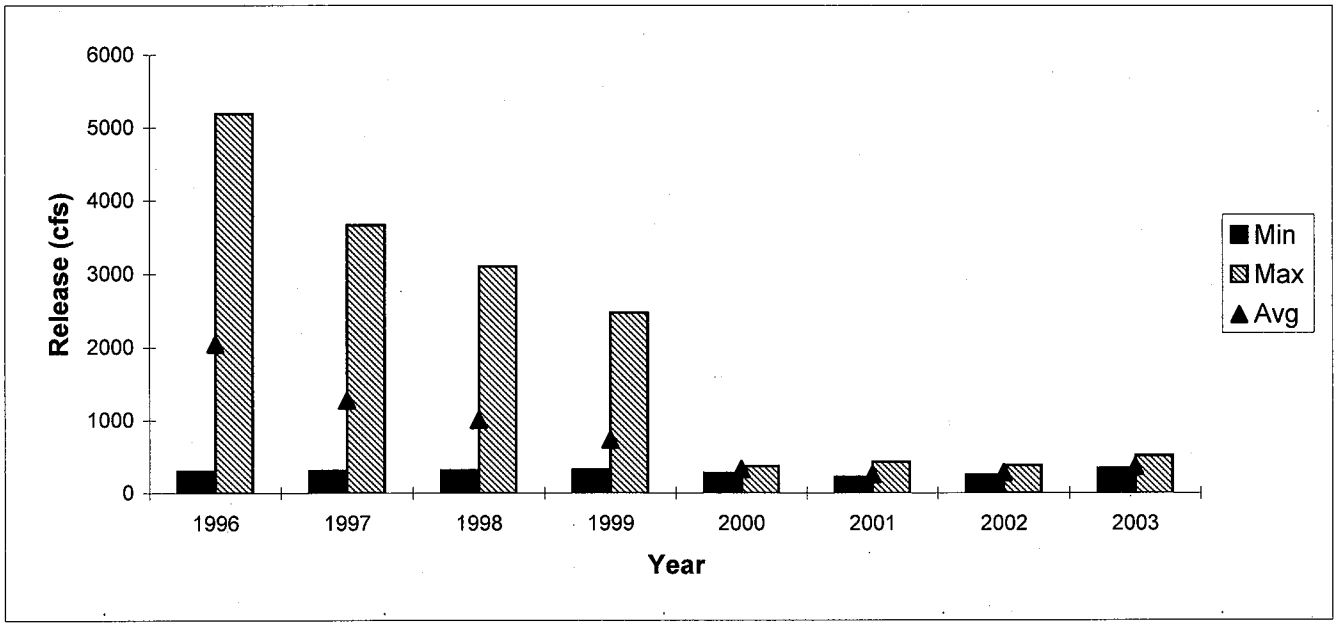

Figure 7. Camanche Dam minimum, maximum and average release during spawning and incubation period (October-April) for the 1996-2003 spawning seasons.

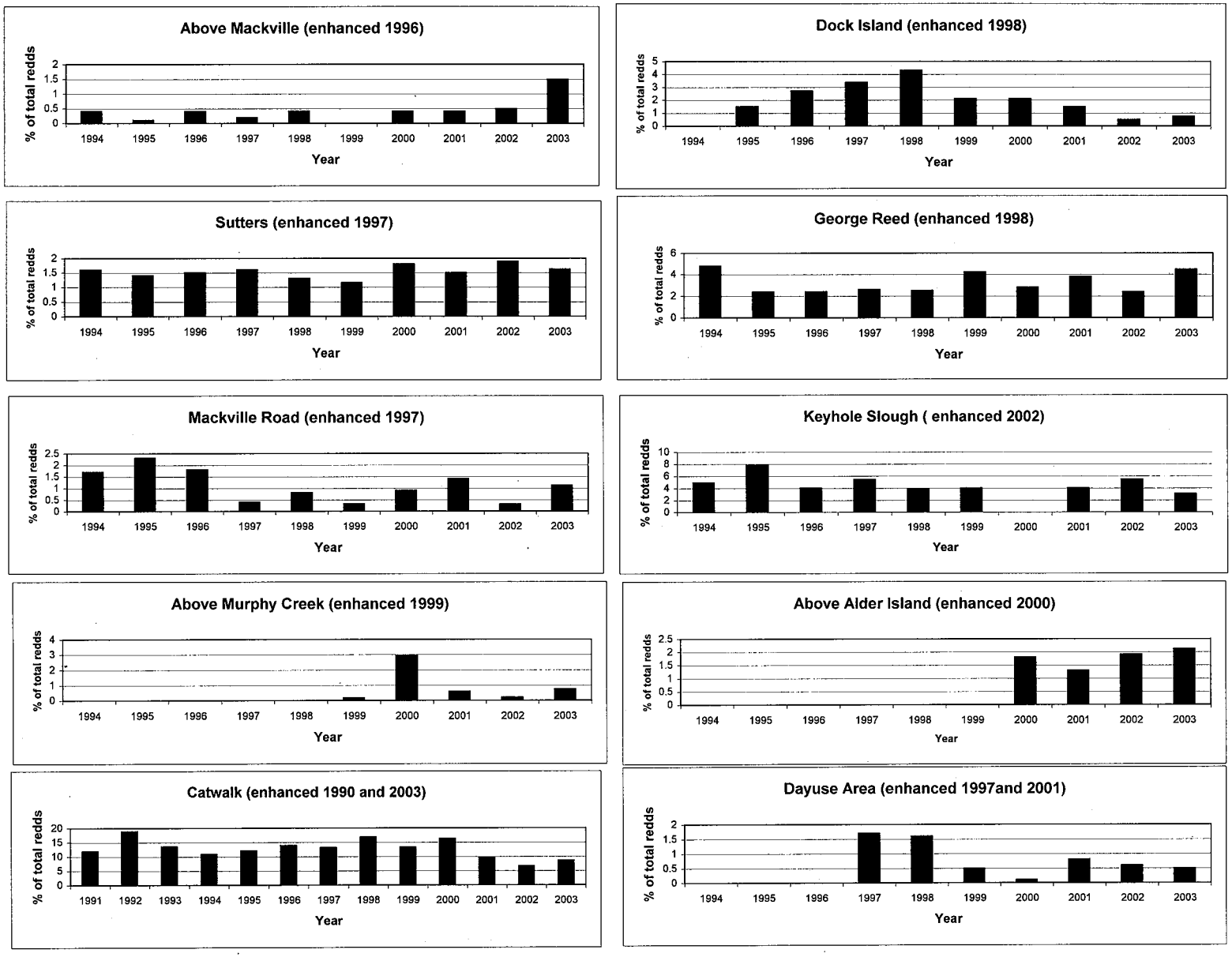

Figure 8. Percent of total redds constructed in sites enhanced since 1996 in the lower Mokelumne River, California 1991-2003.

Table 1. Yearly salmonid spawning survey periods 1996-2003 lower Mokelumne River, CA.

urvey Yea	Start Date	End Date
1996	11-Oct-96	3-Dec-97
1997	1-Oct-97	31-Dec-98
1998	29-Sep-98	26-Jan-99
1999	22-Sep-99	18-Jan-00
2000	2-Oct-00	15-Mar-01
2001	16-Oct-01	20-Mar-02
2002	1-Oct-02	10-Mar-03
2003	24-Sep-03	11-Mar-04

Table 2. Summary of fall-run escapement to the lower Mokelumne River and Mokelumne River Fish Hatchery, California 1990-2003.
Table includes run composition and redd data.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
WID**	#	#	#	#	#	#	#	#	#	#	#	#	#	
Males	190	150	381	1124	1481	2115	2425	4071	2459	1556	2221	^^	4240	3268
Females	153	199	332	1148	1244	2495	2043	5372	2887	1349	2798	^^	4271	4115
Tot adult	343	349	713	2272	2725	4610	4468	9443	5732	3056	5194	^^	8553	7383
Grilse M	128	51	762	703	596	681	2661	540			714	^^	1618	1998
Grilse F	26	10	170	182	100	126	646	180			246	^^	521	615
Tot Grilse	154	61	932	885	696	807	3307	720	1470	2282	1074	^^	2139	
Total Fish	497	410	1645	3157	3421	5517	7920	10175	7213	5335	7418	8114	10755	10240

MFH	#	#	#	#	#	#	#	#	#	#	#	#	#	
Males	16	22	157	794	584	1118	948	3227	1194	792	2082	2021	3286	2280
Females	9	11	107	748	582	1260	880	3070	1311	819	2555	2361	2514	2828
Grilse	50	9	529	750	860	1093	2456	235	585	1542	887	1427	2672	3009
Total Fish	68	41	711	2164	1918	3323	3883	6485	3090	3153	5524	5809	7919	8117
River Fish	429	369	934	993	1503	2094	3892	3678	4112	2185	1894	2305	2834	2121
Females	163	197	313	454	654	1213	1408	2435	1784	568	1141	^^	1757	1287
# Redds	71	127	343	530	774	888	1284@	1325	1116	627	987	843	848	807

** Estimates assume unknown individuals are distributed in the same sex ratio and adult:grilse ratio as known individuals based on Biosystems (1992), VES (1992-1993), NRCS (1993-1994), and NRS, Inc. (1994 -1998).

@ Monitoring ended 12/10/96 due to high flows. At that time the actual redd count was 929. This number is an estimate based on 1992 - 1995 end-of-year average (+/-8.1%).

^^ Sex and age composition was not available for 2002 season.

Table 3. Chinook salmon redd distribution in the lower Mokelumne Rive
California 1996-2003.

Year	Reach 6 Total Nu	%	Reach 5 Total Nu	%
1996	739	79.5	190	20.5
1997	1108	83.8	214	16.2
1998	961	86.1	155	13.9
1999	514	82.5	109	17.5
2000	854	86.5	133	13.5
2001	679	80.5	164	19.5
2002	683	80.5	165	19.5
2003	642	79.5	165	20.5