LOWER MOKELUMNE RIVER FISH COMMUNITY SURVEY. 1 JANUARY 1997 THROUGH 30 JUNE 2004.

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Abstract: A fish community survey was performed on the lower Mokelumne River, California to identify abundance, richness and diversity of native and introduced fish species occurring seasonally and to determine habitat associations of these fish species. Surveys were performed at 59 sample sites over the 7.5-year survey. Thirty-eight (38) species (12 native; 26 introduced) were observed. Juvenile Chinook salmon dominated the seine catch followed by western mosquitofish, prickly sculpin and Sacramento sucker (mostly fry-stage individuals). Prickly sculpin dominated the electrofishing catch followed by juvenile Chinook salmon, adult Sacramento sucker and threadfin shad. Greatest native, introduced and overall species richness was observed in the tidal reaches below Woodbridge Irrigation District Dam (Reach 1: 36 species and Reach 2: 33 species). Reach 2 had the highest over-all species diversity (Spring and Fall 2000) and highest native species diversity (Spring and Fall 2000). Highest introduced species diversity was observed in Reach 4 (Summer 1999 and Winter 2000).

INTRODUCTION

The Federal Energy Regulatory Commission (FERC) November 27, 1998 Order "Approving Settlement Agreement and Amending License for the East Bay Municipal Utility District's Lower Mokelumne River Project No. 2916" approved the March 1998 Mokelumne River Joint Settlement Agreement (Agreement) filed by the East Bay Municipal Utility District (EBMUD), United States Fish and Wildlife Service (USFWS) and California Department of Fish and Game (CDFG). Under the terms of the Agreement, EBMUD, USFWS and CDFG established a Lower Mokelumne River Partnership. Several key objectives of the Partnership are:

- Protection and enhancement of the anadromous fishery;
- Protection and improvement of the Mokelumne River ecosystem;
- Encouragement of stakeholder participation and cooperation; and
- Integration of Mokelumne River strategies with the Bay Delta Accord, Central Valley Project Improvement Act (CVPIA) implementation, or similar measures.

The Partnership Steering Committee, composed of CDFG, USFWS and EBMUD representatives, developed a Water Quality and Resource Management Program (Program) to define reasonable goals, measures, performance criteria and responsive actions associated with the implementation of the agreement. Within this Program, several measures are to be implemented including the maintenance and enhancement of high quality aquatic habitat in the lower Mokelumne River (LMR). A component of the performance criteria for this specific measure is the continued monitoring of fish in the LMR from Camanche Dam downstream to tidewater and in cooperation with others to monitor these communities downstream to the San Joaquin River.

General LMR fish species surveys were performed sporadically over several months during the late 1980s identifying nine confirmed native and 19 introduced fish species (Envirosphere Company 1988; BioSystems Analysis, Inc. 1992). EBMUD has performed annual seining surveys since February 1990 (typically January through June) to assess the health of naturally spawned juvenile fall-run Chinook salmon, *Oncorhynchus tschawytscha*, in the LMR down to Lake Lodi (Fig. 1) (Hartwell 1996). The objective of this continued study is to identify trends in spatial and temporal distribution of the LMR fish assemblage. Specifically, this report identifies abundance, richness and diversity of native and introduced fish species occurring seasonally and determines habitat associations of these fish species within the LMR.

METHODS

Study Area

The Mokelumne River is a snow-fed system that drains approximately 1,624 km^2 of the central Sierra Nevada. Its headwaters begin in the Eldorado National Forest, some 65 km south of Lake Tahoe, at approximately 3,050 m above mean sea level. A tributary of the Sacramento-San Joaquin River system, it enters California's largest delta ~ 48 km southeast of Sacramento. The Mokelumne River presently has 16 major water impoundments, including Salt Springs (175,032,089 m^3), Pardee (258,909,341 m^3) and Camanche reservoirs (531,387,061 m^3).

The LMR ranges in elevation from approximately 28 m at Camanche Dam, the lowest non-passable barrier to anadromous fish, to sea level at Thornton (Fig. 1). The gradient of this section of river ranges from 0.10% near Camanche Dam to 0.02% near the Cosumnes River confluence. Extreme tidal influences are observed as high as RKM 53, Downstream of Woodbridge Dam (Fig.

1). Similar to many other tributaries of the Sacramento-San Joaquin River system, hydraulic mining, gravel extraction, dam construction, water diversions, altered flow regimes, deforestation, artificial bank protection, channelization and levee construction have had a significant influence on channel morphology.

Channel widths of the LMR range from 19 to 43 m with a mean of 30 m. The river tends to be wider in the first 9.5 km below Camanche Dam and, with the exception of Lake Lodi, generally narrower downstream to the tidal reach. Much of the narrowing of the channel downstream can be attributed to flood control levees built to protect homes and farmland on the historical floodplains of the river. There are approximately 64 km of levee constructed on the LMR between Camanche Dam and tidal influence. Tailings from continuing and abandoned gravel mining operations are apparent along the upper third of the LMR. These tailings are isolated from the river by berms and levees although several mining pits are now incorporated into the present river channel or attached as off-channel pools that may be connected or disconnected due to flow and time of year.

Substrates within the LMR channel include limited amounts of gravels and cobbles for about 9.5-14.5 km below Camanche Dam and sand, mud, sandstone or highly compacted alluvium down the remainder of the river. For a complete assessment of LMR habitat, see Merz and Setka (2004a) and Reeves and Jones (2004).

Up to the completion of this report over 35 native and non-native fish species have been observed in the LMR (Merz and Workman 1997; Merz and Setka 2004). These fish include five anadromous species: Fall-run Chinook salmon, winter steelhead trout (*O. mykiss*), American shad (*Alosa sapidissima*), striped bass (*Morone saxatilis*) and Pacific lamprey (*Lampetra tridentata*). Native Chinook salmon and steelhead trout populations are supplemented by fish production at the Mokelumne River Fish Hatchery located at the base of Camanche Dam. Average annual Chinook salmon escapement to the LMR since video monitoring at Woodbridge Dam (Fig. 1) began (1990 – 2002) is 5506 (min: 280; max: 10757) (Workman 2003). Further information on LMR Chinook salmon and steelhead is provided in Merz and Setka (2004b).

Sampling Methods

Habitat classification

A habitat classification system was designed and implemented for the LMR (Merz and Setka 2004). The primary objective of this habitat classification system is to determine the composition, abundance and distribution of riverine habitat to serve as a benchmark against which changes in habitat can be evaluated relative to changes in management activities and time. This system and definitions are based on channel morphology and general hydraulic criteria that distinguish areas, which exhibit similar hydraulic behavior.

The LMR was separated into six reaches based on stream confluences, gradient, tidal influence, and substrate characteristics (Fig. 1):

- Reach I (Mokelumne River Mouth to Cosumnes River confluence),
- Reach II (Cosumnes River confluence to Woodbridge Irrigation District Dam at Lake Lodi),
- Reach III (Woodbridge Irrigation District Dam to Highway 99),
- Reach IV (Highway 99 to Elliott Road),
- Reach V (Elliott Road to Mackville Road), and
- Reach VI (Mackville Road to Camanche Dam) were surveyed.

The reaches are further stratified into habitat types. Habitat types are identified and assigned to 1 of 6 habitats (Merz and Setka 2004a): 1) channel pools (unbroken surface, slow velocity, deep water), 2) glides (moderately shallow water with an even flow that lacked pronounced turbulence), 3) runs (rippled surface, fast velocity, shallow water), 4) riffles (stream bed substrate protruding through water surface), 5) island complexes (sections of river dominated by longitudinal bars of bed material that typically split the channel during normal flow periods, and 6) off-channel pools (slow, deep water adjacent but contiguous to the main channel). For a complete assessment of LMR aquatic habitat, see Merz and Setka (2004a).

For this study, specific sites representative of major habitats present in each reach were selected for fish community sampling. Seining and backpack electrofishing was performed once monthly from January through June of each year to collect information on juvenile fish (primarily Chinook salmon and steelhead). Seasonal surveys were performed annually by all three methods (including boat electrofishing) during January (Winter), early-May (Spring), late-July (Summer) and October (Fall).

Seining procedures- A 50 ft x 6 ft -1/16 inch mesh (15.25 m x 1.8 m - 0.16 cm) beach seine with 1.5 inch (38 mm) diameter wooden support poles was used to make one to three hauls (typically two) during daylight within each sample site. Depth of seining was less than 6 ft (1.8 m), velocities less than 3 ft/s (0.92 m/s) and we attempted to seine areas with substrates free of large obstructions that would hinder the movement of the seine. A 50 ft (15.25 m) rope was attached to each support pole at the ends of the seine. Two people walked the seine out into the river while two people held the ropes from the bank. The net was deployed at the end of the 50 ft (15.25 m) ropes or at a water depth of 6 ft (1.8 m) and the distance was noted. One person began moving downstream to deploy the seine as the upstream member remained stationary. The two crew members on the bank did the same. The two people on shore assisted by pulling in the net as the two people in the river began moving the net toward shore. Two markers were placed where the two ends of the seine first reached the bank. The measurement of site length multiplied by the distance out from shore provides an estimate of area seined. The two people holding the poles continued to pull the ends of the seine in while the two rope handlers assisted in keeping the lead line down and pulling the net on shore. When the net was completely retrieved, captured fish were removed from the net and placed in a large container of river water. Captured fish were enumerated and released live to the river.

Backpack electrofishing surveys- Shallow riffles and runs (<0.61 m depth; >0.6 m • sec^{-1}) were electrofished monthly. A 25 ft x 6 ft -1/16 inch mesh (7.6 m x 1.8 m - 0.16 cm) beach seine with 1.5 inch (38 mm) diameter wooden support poles was deployed perpendicular to stream flow by two people. Markers were placed on the substrate, at the corner of each seine pole. A third person used a Smith - Root Model 12 backpack electrofisher to sample the area approximately 15 ft (4.6 m) upstream of the seine and within the seine area. A marker was placed where the third person began sampling. After the area was sampled, the lead line of the seine was immediately raised to prevent the loss of fish captured in the seine. Captured fish were enumerated, measured, weighed and released live in the river. For seining and backpack electrofishing, depth, velocity and area (sq. meters) within the markers were recorded. These data were used to estimate total area sample as a means to calculate a catch-per-unit effort (CPUE) (e.g. number of fish per m^3 of water sampled).

Boat electrofishing surveys- Selected deep and swift water (velocities > .91 m/s) habitats were sampled with a Smith-Root SR-18E electrofishing boat during the spring following the methods described in Meador et al. (1993). An automatic timer was used to measure the total length of time a specific site was sampled to calculate a CPUE (e.g. number of fish per second).

After enumeration, fish were immediately released at the sample site except for those kept and preserved for diet analysis studies (see Merz 2002a; Merz 2002b; Merz 2001) or various State and Federal monitoring programs.

In addition to lists of species observed, estimates of relative abundance (number of individuals of each species per habitat sampled); species richness (total number of species detected); and species diversity were developed.

Species diversity (H), as described by Schemnitz (1980), was calculated as:

$$H = \sum_{i=1}^{n} p_i \log p_i$$

Where there are n possible categories in a data set and their proportions are $p_i, \ldots, p_n$.

Divergence from equiprobability (D), as described by Luo (1998), was calculated as:

$$D = H_{max} - H$$

Where H_{max} is the maximum H can be with the given number of species in a sample and is calculated as $H_{max} = \log(1/\# \text{ of categories})$

Species Evenness was calculated as:

$$E = H/\log(s) \bullet 100$$

Where s = species richness

Where E = 100 when all species have the same proportions and E ~ 0 when species abundance differs greatly.

RESULTS

Annual Camanche Reservoir and WIDD releases are provided in Figure 2. Annual river temperatures at Camanche Dam, Mackville Road, Woodbridge Dam and Frandy stations are provided in Figure 3. Fifty-nine sample sites were monitored by one or more of the three sampling methods (seine; boat and back-pack electro-fishing) within the 6 river reaches.

Thirty-eight fish species were collected overall, including several specimens of hybrid centrarchids which are considered a unique, single species (*Lepomis* x.) for measures of species richness and diversity (Seining: 32; Electrofishing: 36)(Table 1). Juvenile Chinook salmon dominated the seine catch followed by western mosquitofish, prickly sculpin and Sacramento sucker, *Catostomus occidentalis* (mostly fry-stage individuals).

Prickly sculpin dominated the electrofishing catch followed by juvenile Chinook salmon, adult Sacramento suckers and threadfin shad (*Dorosoma petenense*). The three-spined stickleback (*Gasterosteus aculeatus*) has been observed in surveys of Murphy Creek (Fig. 1) but not in the mainstem of the LMR. Similarly, single specimens of sturgeon (*Acipenser* sp.) and California roach (*Lavinia symmetricus*) have been observed in the rotary screwtrap at Woodbridge Dam but not within the confines of this study (Workman 2004).

Fish Species By River Reach- Reaches 1 and 2 had the highest number of native (11), introduced (22), and overall (33) numbers of species during the survey (Table 2). Reach 4 had the highest ratio (1:1.4) and Reach 2 had the lowest ratio (1: 3.3) of native to introduced fish species.

Species Richness and Diversity By Habitat- These data are provided in Tables 3 – 8. Greatest overall species richness was observed in the tidal glide habitat of Reach 1 during 2001 and 2002 (33 species) (Table 3). This was also the same for native and introduced species richness (10 and 23 respectively). In the non-tidal reach of the LMR, contiguous, off-channel pool habitat of Reach 6 had the highest species richness (15 species in 2004), followed by glide habitat of Reach 5 in 2001 and 2002 (14 species; Tables 7 and 8). Greatest native species richness above tidewater was observed in glide habitat of Reaches 4 and 5 over several years (8 species; Tables 6 and 7). Greatest introduced species richness above tidewater was observed in contiguous, off-channel pool habitat in Reaches 5 and 6 (11 species; Tables 7 and 8). Greatest overall diversity was observed at the confluence of the Mokelumne River and Deadhorse Slough in 2001 (H = 3.78; Table 3). The same was true for introduced species diversity (H = 3.38). Greatest native species diversity was observed in 2004 in the large pool at the basin of the Woodbridge Irrigation District Dam (H = 2.69; Table 4).

In the non-tidal section, greatest overall species diversity was observed in 2004 within the glide habitat of Reach 5 (H = 2.88; Table 5). Greatest native species diversity within the non-tidal section was observed in glide habitat of Reach 4 during the 2004 sampling year (Table 4).

Summary

The lower Mokelumne River has a diverse population of native and non-native fish species. Overall, greatest species richness and diversity appears to occur in the lower 2 reaches of LMR, primarily due to a high number of introduced species. This may be the result of several influences including, tidal water, proximity to other waterways and the effects of Woodbridge Irrigation District Dam on the movement of some fish above tidewater. Similarly, contiguous, off-channel pools within the reaches above tidewater also have the highest richness and diversity, due primarily to introduced species. The most intact habitats, as indicated by high native and low introduced fish species, appear to occur in main-channel glides, runs and riffles, where water residence time is short and most likely temperatures remain relatively cool. However, this assessment does not take into account the variety of habitat requirements needed by any given fish species over a variety of life histories.

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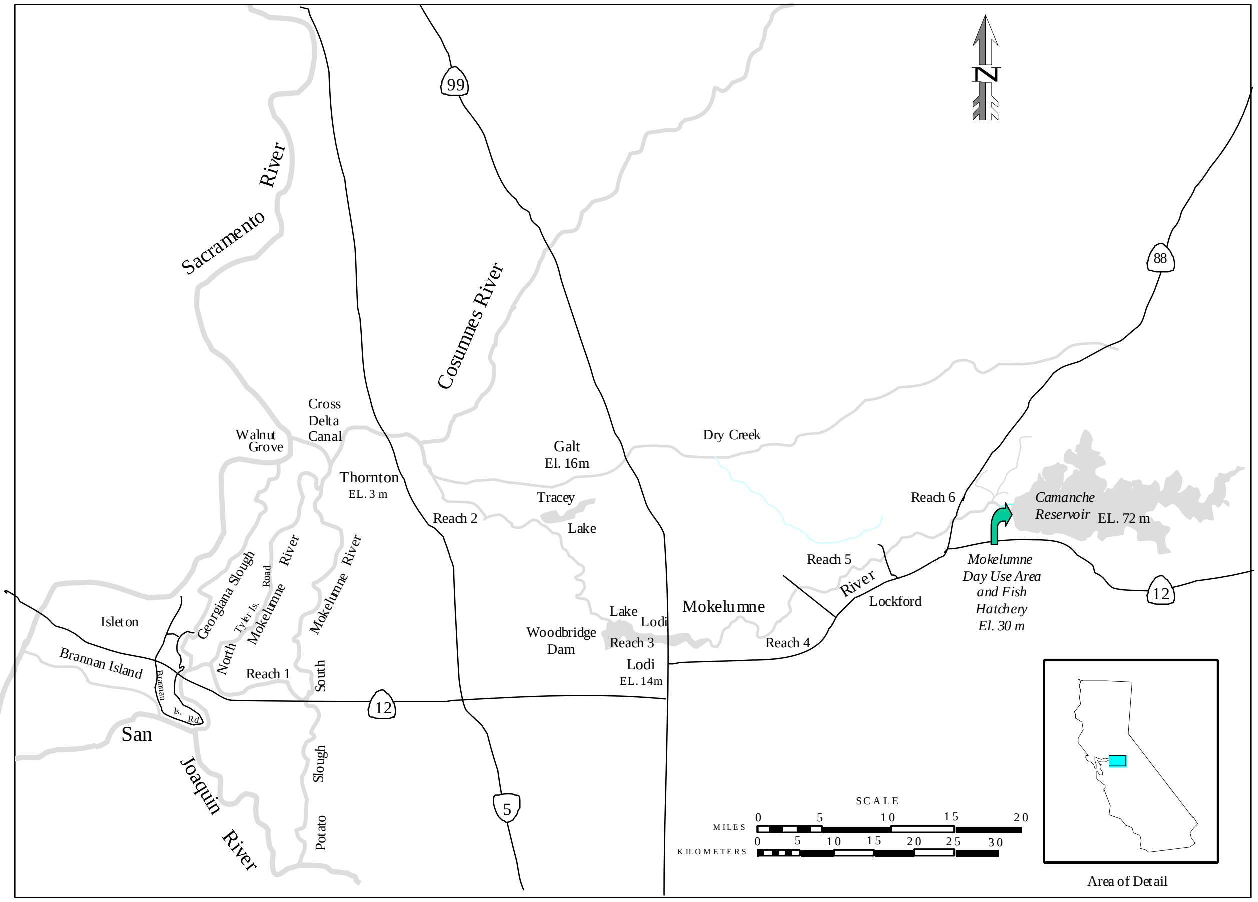

Figure 1. The lower Mokelumne River and associated Sacramento- San Joaquin Delta.

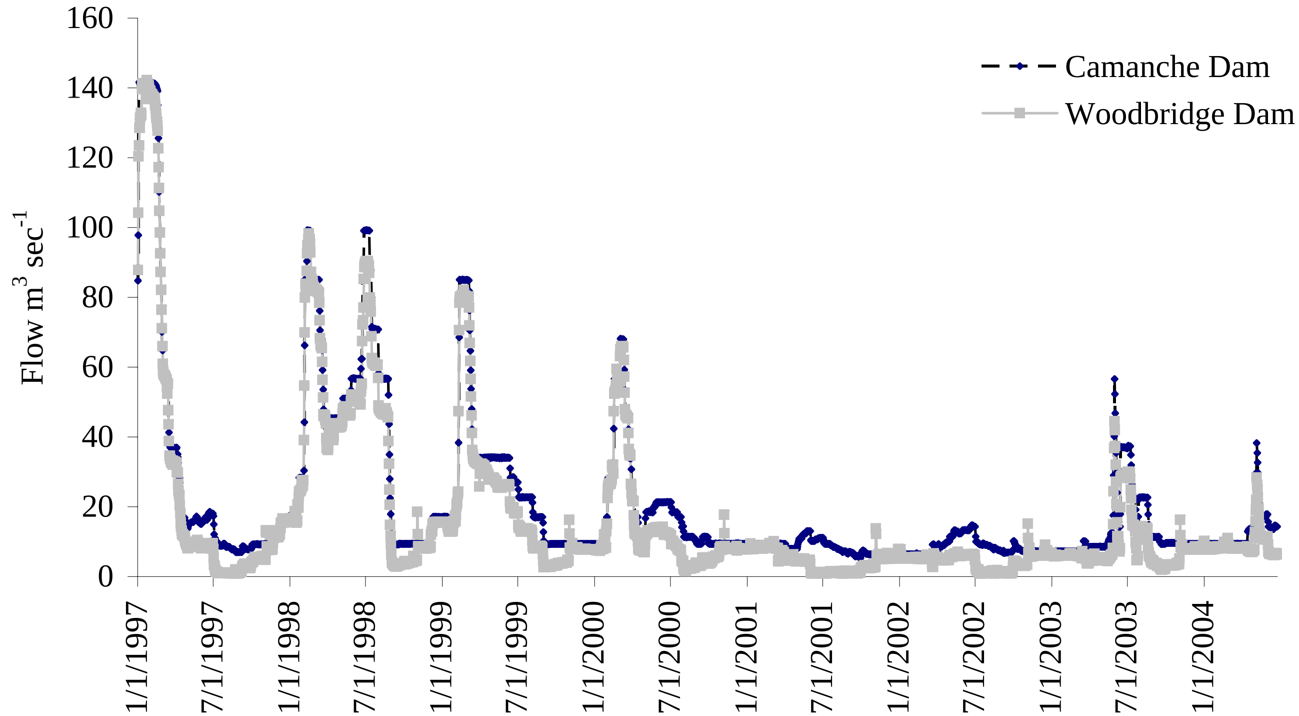

Figure 2. River flow recorded at Camanche and Woodbridge dams, lower Mokelumne River California. 1 January 1997 through 30 June 2004.

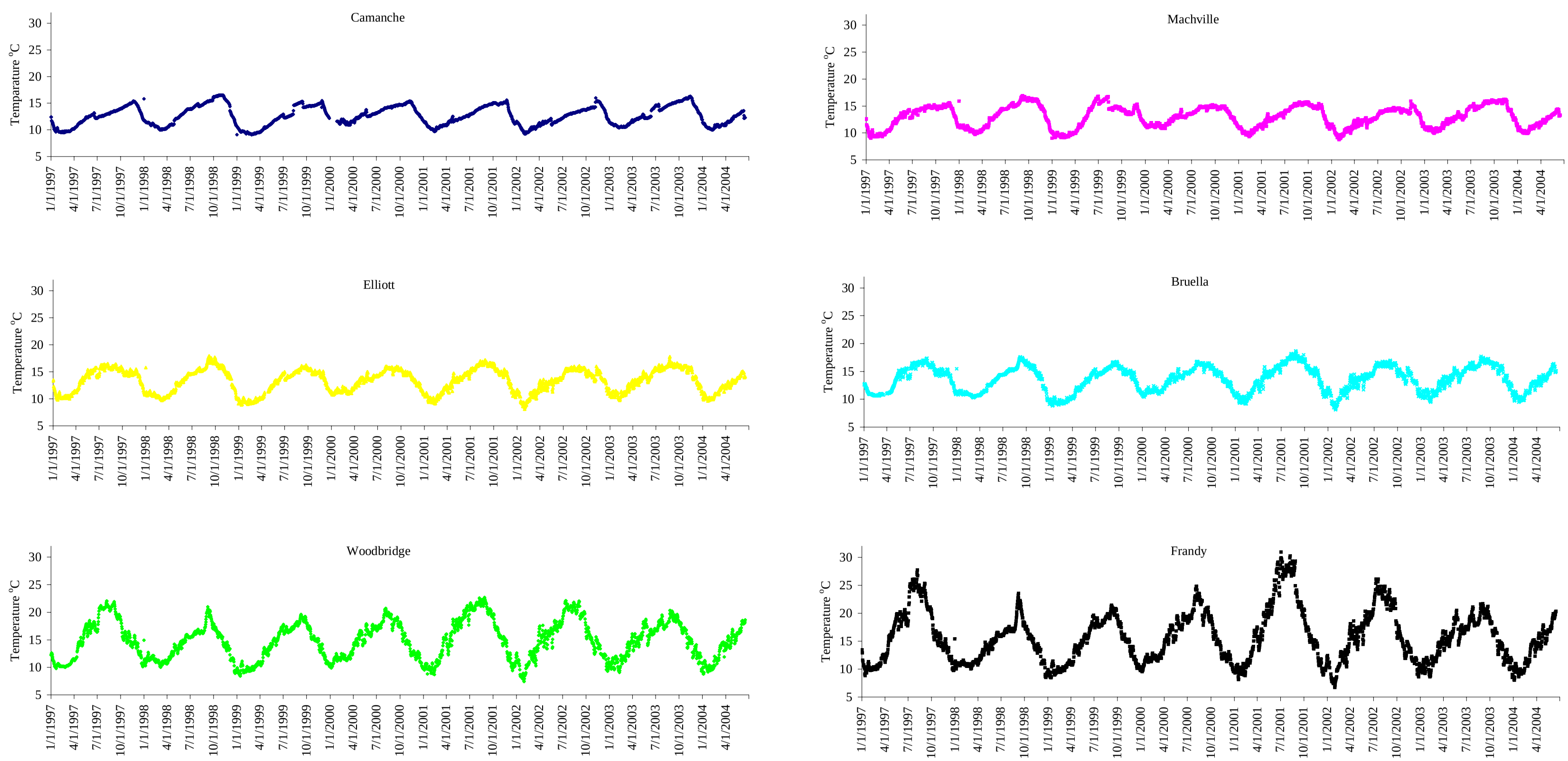

Figure 3. Mean daily temperature recorded within the lower Mokelumne River at six monitoring stations, 1 January 1997 through 30 June 2004.

Table 1. Observations of species and numbers of fish captured by electrofishing and seining in the lower Mokelumne River, California. January 1997 through June 2004.

Reach	1		2				3				4				5				6					
	E-Fish[1]		Seine		E-Fish		Seine		E-Fish		Seine		E-Fish		Seine		E-Fish		Seine		E-Fish		Native	
Native Species	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Total	%
Chinook Salmon	191	18	825	36	4774	61	64	3	571	31	3793	45	433	12	6664	47	500	13	5311	28	1561	15	24687	33
Delta Smelt	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Hardhead	0	0	0	0	5	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	8	0
Hitch	8	1	138	6	98	1	11	1	53	3	347	4	152	4	413	3	145	4	452	2	1181	11	2998	4
Pacific Lamprey	19	2	13	1	279	4	0	0	82	4	18	0	302	8	26	0	221	6	0	0	14	0	974	1
Prickly Sculpin	104	10	302	13	351	4	195	10	528	28	2040	24	1423	40	2846	20	1659	43	12137	65	4480	42	26065	35
Sacramento Blackfish	3	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	10	0
Sacramento Pikeminnow	76	7	378	17	551	7	2	0	8	0	348	4	27	1	426	3	49	1	5	0	42	0	1912	3
Sacramento Splittail	9	1	0	0	22	0	0	0	0	0	17	0	0	0	4	0	0	0	0	0	0	0	52	0
Sacramento Sucker	466	45	579	26	1023	13	1654	85	296	16	1770	21	719	20	3392	24	966	25	389	2	2335	22	13589	18
Steelhead Trout	62	6	1	0	419	5	2	0	206	11	60	1	244	7	384	3	276	7	388	2	1036	10	3078	4
Tule Perch	108	10	26	1	330	4	9	0	115	6	118	1	296	8	4	0	17	0	1	0	5	0	1029	1
Subtotals	1047		2262		7856		1937		1860		8512		3596		14161		3833		18683		10656		74403	100
	Total	%		Total	%			Total	%			Total	%			Total	%			Total	%		Total	%
Native Individuals	1047	1		10118	14			3797	5			12108	16			17994	24			29339	39		74403	100
Native species	11	92		11	92			9	75			10	83			10	83			9	75		12	100
Introduced Species																								
American Shad	349	4	0	0	99	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	448	1
Bigscale Logperch	22	0	19	1	5	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	47	0
Black Bullhead	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Black Crappie	75	1	0	0	7	0	0	0	0	0	13	0	0	0	88	1	1	0	3	0	18	2	205	1
Bluegill	727	9	68	2	369	10	1	0	7	5	63	1	523	28	206	3	17	5	34	1	118	12	2133	6
Brown Bullhead	15	0	3	0	5	0	0	0	0	0	3	0	2	0	4	0	0	0	9	0	15	2	56	0
Channel Catfish	16	0	3	0	22	1	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	45	0
Common Carp	138	2	1	0	108	3	0	0	6	4	259	4	68	4	0	0	3	1	12	0	37	4	632	2
Golden Shiner	342	4	85	3	34	1	15	5	9	7	3873	54	864	46	526	8	191	52	138	3	46	5	6123	17
Goldfish	7	0	1	0	6	0	0	0	4	3	0	0	3	0	0	0	24	6	1	0	33	3	79	0
Green Sunfish	36	0	1	0	7	0	0	0	5	4	1	0	63	3	31	0	14	4	86	2	5	1	249	1
Inland Silverside	1368	17	127	5	586	16	0	0	1	1	0	0	0	0	2	0	0	0	2	0	0	0	2086	6
Kokanee	0	0	0	0	0	0	0	0	0	0	10	0	1	0	2	0	0	0	2	0	1	0	16	0
Largemouth Bass	622	8	10	0	117	3	44	16	47	35	545	8	19	1	32	0	18	5	9	0	110	11	1573	4
Lepomis hybrid	49	1	10	0	19	1	19	7	0	0	0	0	3	0	27	0	1	0	17	0	6	1	151	0
Readear Sunfish	766	10	26	1	193	5	0	0	2	1	50	1	8	0	20	0	1	0	1	0	2	0	1069	3
Redeye Bass	223	3	4	0	84	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	311	1
Smallmouth Bass	16	0	12	0	27	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0
Spotted Bass	952	12	21	1	158	4	118	42	43	32	105	1	32	2	21	0	18	5	7	0	54	6	1529	4
Striped Bass	121	2	1	0	587	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	709	2
Thredfin Shad	1590	20	0	0	1054	30	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2646	7
Unidentified Black Bass[2]	28	0	5	0	32	1	28	10	10	7	4	0	4	0	1	0	1	0	0	0	4	0	117	0
Unknown[2]	0	0	1	0	3	0	0	0	0	0	6	0	9	0	5	0	4	1	0	0	5	1	33	0
Unknown Cyprinid[2]	0	0	1	0	0	0	0	0	0	0	7	0	2	0	0	0	0	0	0	0	1	0	11	0
Warmouth	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	0
Western Mosquitofish	2	0	2358	85	13	0	53	19	0	0	2201	31	272	15	5722	86	76	21	4638	93	524	53	15859	43
White Catfish	1	0	3	0	11	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	17	0
White Crappie	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Yellowfin Goby	354	5	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	360	1
Subtotals	7861		2760		3552		278		135		7141		1873		6688		370		4963		980		36601	
	Total	%		Total	%			Total	%			Total	%			Total	%			Total	%		Total	%
Introduced individuals	7861	21		6312	17			413	1			9014	25			7058	19			5943	16		36601	100
Introduced species	25	96		22	85			12	46			14	54			16	62			17	65		26	100
Total individual	8908	8		16430	14			4210	4			21122	19			25052	23			35282	32		111004	100
Total species	36	95		33	87			21	55			24	63			26	68			26	68		38	100

Seine includes backpack-electrofish

[1]Boat electrofish

[2]Not counted as species

Table 2. Fish species observations, richness, diversity, and abundance by reach and season in the lower Mokelumne River, San Joaquin and Sacramento counties, CA 1997-2004

H=species diversity; D=divergence from equiprobability; E=evenness

Year	Season	Reach	Overall $N_{individuals}$	Overall relative abundance	Native $N_{individuals}$	Native relative abundance	Introduced $N_{individuals}$	Introduced relative abundance	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
1997	Spring	4	25	0.0139	22	0.0122	3	0.0017	5	3	2	1.96	1.50	0.918	0.360	0.082	0.082	84.5	94.8	91.8
1997	Spring	5	88	0.0345	88	0.0345	0	0.0000	4	4	0	1.26	1.26		0.735	0.735		63.2	63.2	
1997	Spring	6	305	0.5476	270	0.4847	35	0.0628	13	6	7	2.43	1.87	2.29	1.27	0.720	0.513	65.6	72.2	81.7
1997	Fall	3	2	0.0025	2	0.0025	0	0.0000	1	1	0	0	0		0	0				
1997	Fall	4	126	0.0027	80	0.0017	46	0.0010	13	7	6	2.69	1.92	1.44	1.01	0.888	1.14	72.8	68.4	55.9
1997	Fall	5	90	0.0020	90	0.0020	0	0.0000	5	5	0	1.74	1.74		0.583	0.583		74.9	74.9	
1997	Fall	6	390	0.0034	372	0.0032	18	0.0002	15	6	9	2.53	2.22	3.04	1.38	0.368	0.126	64.6	85.8	96.0
1998	Winter	2	89	0.0012	73	0.0009	16	0.0002	12	6	6	2.69	1.98	2.18	0.892	0.609	0.405	75.1	76.5	84.3
1998	Winter	3	32	0.0051	26	0.0041	6	0.0009	8	4	4	1.92	1.07	1.92	1.08	0.932	0.082	64.1	53.4	95.9
1998	Winter	4	159	0.0028	149	0.0026	10	0.0002	11	7	4	2.48	2.16	1.85	0.982	0.650	0.154	71.6	76.9	92.3
1998	Winter	5	37	0.0034	37	0.0034	0	0.0000	4	4	0	1.77	1.77		0.234	0.234		88.3	88.3	
1998	Winter	6	118	0.0053	109	0.0049	9	0.0004	9	5	4	1.99	1.59	1.66	1.18	0.730	0.342	62.6	68.5	82.9
1998	Spring	2	365	0.0022	310	0.0019	55	0.0003	15	7	8	1.92	1.14	2.23	1.99	1.66	0.763	49.1	40.7	74.5
1998	Spring	3	36	0.0023	33	0.0021	3	0.0002	5	3	2	1.57	1.18	0.918	0.751	0.406	0.082	67.7	74.4	91.9
1998	Spring	4	157	0.0032	157	0.0032	0	0.0000	5	5	0	1.25	1.25		1.07	1.07		53.8	53.8	
1998	Spring	5	61	0.0030	61	0.0030	0	0.0000	5	5	0	1.42	1.42		0.901	0.901		61.2	61.2	
1998	Spring	6	372	0.0036	302	0.0029	70	0.0007	15	6	9	2.79	2.09	2.13	1.11	0.498	1.04	71.5	80.7	67.9
1998	Summer	2	151	0.0019	75	0.0009	76	0.0009	20	8	12	2.82	2.35	1.30	1.50	0.654	2.28	65.3	78.2	36.3
1998	Summer	3	7	0.0052	7	0.0052	0	0.0000	1	1	0	0	0		0	0				
1998	Summer	4	135	0.0049	105	0.0038	30	0.0011	9	7	2	2.38	1.98	0.353	0.788	0.829	0.646	75.1	70.5	35.3
1998	Summer	5	25	0.0045	25	0.0045	0	0.0000	3	3	0	1.02	1.02		0.569	0.569		64.1	64.1	
1998	Fall	2	4156	0.1505	4071	0.1474	85	0.0031	15	7	8	0.229	0.053	1.60	3.68	2.75	1.40	5.90	1.89	53.4
1998	Fall	3	6	0.0029	4	0.0019	2	0.0010	5	3	2	2.25	1.50	1.00	0.07	0.085	0	97.0	94.6	100
1998	Fall	4	89	0.0053	79	0.0047	10	0.0006	9	5	4	2.59	2.10	1.90	0.582	0.218	0.105	81.6	90.6	94.8
1998	Fall	5	91	0.0027	88	0.0026	3	0.0001	8	5	3	2.19	1.99	1.58	0.810	0.327	0	73.0	85.9	100
1998	Fall	6	301	0.0062	284	0.0059	17	0.0004	15	6	9	2.34	1.98	2.89	1.56	0.606	0.280	60.0	76.6	91.2
1999	Winter	2	501	0.0075	470	0.0071	31	0.0005	16	5	11	1.78	1.36	2.82	2.22	0.964	0.639	44.6	58.5	81.5
1999	Winter	3	33	0.0030	30	0.0027	3	0.0003	7	4	3	1.83	1.37	1.58	0.977	0.628	0	65.2	68.6	100
1999	Winter	4	196	0.0041	196	0.0041	0	0.0000	6	6	0	1.88	1.88		0.703	0.703		72.8	72.8	
1999	Winter	5	118	0.0064	118	0.0064	0	0.0000	5	5	0	1.86	1.86		0.460	0.460		80.2	80.2	
1999	Winter	6	373	0.0052	357	0.0050	16	0.0002	10	5	5	2.35	2.10	1.91	0.976	0.223	0.416	70.6	90.4	82.1
1999	Spring	2	126	0.0018	111	0.0016	15	0.0002	11	5	6	2.36	1.78	2.23	1.10	0.545	0.359	68.1	76.5	86.1
1999	Spring	3	24	0.0017	23	0.0017	1	0.0001	5	4	1	1.64	1.45	0	0.679	0.546	0	70.8	72.7	
1999	Spring	4	265	0.0048	264	0.0048	1	0.0000	6	5	1	1.77	1.74	0	0.816	0.582	0	68.4	74.9	
1999	Spring	5	44	0.0056	44	0.0056	0	0.0000	5	5	0	1.86	1.86		0.465	0.465		80.0	80.0	
1999	Spring	6	333	0.0053	318	0.0051	15	0.0002	11	6	5	2.37	2.10	2.02	1.09	0.481	0.300	68.4	81.4	87.1
1999	Summer	2	313	0.0046	124	0.0018	189	0.0028	22	7	15	2.90	1.89	1.95	1.56	0.919	1.95	65.0	67.3	50.0
1999	Summer	3	7	0.0021	7	0.0021	0	0.0000	3	3	0	1.49	1.49		0.436	0.436		72.5	72.5	
1999	Summer	4	223	0.0044	223	0.0044	0	0.0000	5	5	0	1.95	1.95		0.377	0.377		83.8	83.8	
1999	Summer	5	107	0.0041	106	0.0041	1	0.0000	7	6	1	2.17	2.11	0	0.641	0.475	0	77.2	81.6	
1999	Summer	6	665	0.0063	630	0.0060	35	0.0003	12	5	7	2.05	1.73	2.22	1.54	0.596	0.589	57.2	74.3	79.0
1999	Fall	5	99	0.0081	96	0.0079	3	0.0002	6	3	3	0.977	0.756	1.58	1.61	0.829	0	37.8	47.7	100
1999	Fall	6	610	0.0096	591	0.0093	19	0.0003	10	6	4	1.57	1.37	1.37	1.76	1.22	0.627	47.1	52.8	68.6
2000	Winter	3	214	0.0043	194	0.0039	20	0.0004	13	7	6	1.96	1.42	2.37	1.74	1.38	0.219	52.0	50.7	91.5
2000	Winter	4	16	0.0427	16	0.0427	0	0.0000	5	5	0	2.10	2.10		0.222	0.222		90.4	90.4	
2000	Spring	2	253	0.0019	203	0.0016	50	0.0004	18	9	9	3.31	2.52	2.90	0.859	0.653	0.268	79.4	79.4	91.5
2000	Spring	3	39	0.0027	35	0.0024	4	0.0003	4	2	2	1.33	0.863	0.811	0.665	0.137	0.189	66.7	86.3	81.1
2000	Spring	4	620	0.0133	337	0.0072	283	0.0061	10	7	3	2.15	1.79	0.39	1.17	1.01	1.19	64.7	63.9	24.6
2000	Spring	5	294	0.0088	294	0.0088	0	0.0000	6	6	0	1.73	1.73		0.858	0.858		66.8	66.8	
2000	Spring	6	864	0.0103	748	0.0089	116	0.0014	12	6	6	2.39	1.99	0.753	1.20	0.600	1.83	66.6	76.8	29.1
2000	Summer	1	194	0.0040	16	0.0003	178	0.0037	13	2	11	1.64	0.896	1.26	2.06	0.104	2.20	44.4	89.6	36.5
2000	Summer	2	281	0.0021	171	0.0013	110	0.0008	22	8	14	3.29	1.92	2.95	1.17	1.08	0.860	73.7	63.9	77.4
2000	Summer	3	39	0.0015	10	0.0004	29	0.0011	5	3	2	1.42	1.30	0.362	0.900	0.29	0.638	61.3	81.7	36.2
2000	Summer	4	276	0.0050	264	0.0048	12	0.0002	12	8	4	1.88	1.61	1.73	1.71	1.39	0.270	52.4	53.8	86.5
2000	Summer	5	602	0.0102	589	0.0100	13	0.0002	11	7	4	1.61	1.46	1.55	1.84	1.34	0.453	46.7	52.1	77.3
2000	Summer	6	846	0.0077	825	0.0075	21	0.0002	11	4	7	1.77	1.58	2.51	1.69	0.42	0.297	51.2	79.0	89.4
2000	Fall	1	355	0.0032	115	0.0010	240	0.0022	16	5	11	2.93	1.35	2.34	1.07	0.967	1.12	73.2	58.3	67.5
2000	Fall	2	215	0.0021	148	0.0014	67	0.0006	19	7	12	3.51	2.41	3.07	0.736	0.397	0.512	82.7	85.9	85.7
2000	Fall	3	17	0.0028	14	0.0023	3	0.0005	6	4	2	2.09	1.52	0.918	0.497	0.478	0.082	80.8	76.1	91.8
2000	Fall	4	407	0.0059	307	0.0044	100	0.0014	12	7	5	1.96	1.33	0.638	1.62	1.48	1.68	54.8	47.4	27.5
2000	Fall	5	52	0.0082	51	0.0081	1	0.0002	6	5	1	1.80	1.69	0	0.786	0.627	0	69.6	73.0	
2000	Fall	6	608	0.0072	553	0.0066	55	0.0007	12	6	6	2.43	2.05	1.43	1.16	0.538	1.16	67.8	78.2	55.2

Table 2 continued-

H=species diversity; D=divergence from equiprobability; E=evenness

Year	Season	Reach	Overall $N_{individuals}$	Overall relative abundance	Native $N_{individuals}$	Native relative abundance	Introduced $N_{individuals}$	Introduced relative abundance	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
2001	Winter	1	478	0.0036	82	0.0006	396	0.0030	24	8	16	2.47	2.26	1.72	2.11	0.744	2.28	54.0	75.2	43.0
2001	Winter	2	206	0.0025	187	0.0023	19	0.0002	15	7	8	2.36	1.85	2.59	1.55	0.960	0.410	60.4	65.8	86.6
2001	Winter	3	30	0.0025	27	0.0022	3	0.0002	7	4	3	2.26	1.82	1.58	0.542	0.181	0	80.7	91.0	100
2001	Winter	4	329	0.0048	322	0.0047	7	0.0001	13	8	5	2.31	2.16	2.24	1.39	0.839	0.086	62.5	72.0	96.3
2001	Winter	5	263	0.0048	257	0.0046	6	0.0001	12	7	5	2.08	1.92	2.25	1.50	0.888	0.070	58.1	68.4	97.0
2001	Winter	6	549	0.0057	534	0.0056	15	0.0002	14	6	8	2.38	2.18	2.87	1.43	0.409	0.127	62.4	84.2	95.8
2001	Spring	1	286	0.0025	94	0.0008	192	0.0016	26	8	18	3.61	2.32	2.88	1.09	0.682	1.29	76.8	77.3	69.1
2001	Spring	2	227	0.0024	192	0.0021	35	0.0004	19	9	10	3.16	2.49	2.82	1.09	0.680	0.505	74.4	78.5	84.8
2001	Spring	3	14	0.0022	13	0.0020	1	0.0002	3	2	1	1.26	0.961	0	0.321	0.039	0	79.7	96.1	
2001	Spring	4	337	0.0057	333	0.0057	4	0.0001	9	7	2	2.07	2.00	0.811	1.10	0.812	0.188	65.4	71.1	81.1
2001	Spring	5	298	0.0067	296	0.0066	2	0.0000	10	8	2	2.13	2.08	1.00	1.19	0.917	0	64.2	69.4	100
2001	Spring	6	730	0.0057	707	0.0056	23	0.0002	14	7	7	2.26	2.06	2.11	1.55	0.750	0.700	59.4	73.3	75.1
2001	Summer	1	937	0.0025	86	0.0002	851	0.0023	25	5	20	3.09	1.04	2.81	1.55	1.29	1.51	66.6	44.6	65.1
2001	Summer	2	1783	0.0124	128	0.0009	1655	0.0115	23	7	16	1.76	1.83	1.36	2.76	0.980	2.64	39.0	65.2	33.9
2001	Summer	3	39	0.0026	22	0.0015	17	0.0012	5	4	1	1.70	1.27	0	0.619	0.732	0	73.4	63.4	
2001	Summer	4	524	0.0155	160	0.0047	364	0.0108	13	7	6	1.72	1.87	0.381	1.98	0.936	2.20	46.6	66.7	14.7
2001	Summer	5	236	0.0068	228	0.0065	8	0.0002	12	7	5	1.84	1.62	2.00	1.74	1.19	0.322	51.5	57.6	86.1
2001	Summer	6	425	0.0045	389	0.0041	36	0.0004	13	6	7	2.26	1.84	1.95	1.44	0.749	0.856	61.2	71.0	69.5
2001	Fall	1	1140	0.0024	78	0.0002	1062	0.0022	24	5	19	3.38	1.35	3.15	1.20	0.971	1.1	73.8	58.2	74.0
2001	Fall	2	345	0.0031	250	0.0023	95	0.0009	20	7	13	3.35	2.22	3.23	0.974	0.585	0.475	77.5	79.2	87.2
2001	Fall	3	16	0.0045	14	0.0039	2	0.0006	3	2	1	0.868	0.371	0	0.717	0.629	0	54.8	37.1	
2001	Fall	4	290	0.0028	146	0.0014	144	0.0014	12	6	6	2.97	2.00	1.95	0.612	0.587	0.637	82.9	77.3	75.3
2001	Fall	5	213	0.0040	180	0.0034	33	0.0006	11	7	4	2.77	2.33	1.16	0.688	0.478	0.837	80.1	83.0	58.1
2001	Fall	6	492	0.0042	478	0.0041	14	0.0001	11	6	5	2.24	2.05	2.16	1.22	0.538	0.166	64.7	79.2	92.9
2002	Winter	1	355	0.0019	34	0.0002	321	0.0017	18	5	13	2.60	1.94	2.16	1.57	0.378	1.54	62.2	83.7	58.4
2002	Winter	2	164	0.0019	122	0.0014	42	0.0005	15	7	8	3.37	2.54	2.56	0.54	0.265	0.444	86.2	90.6	85.2
2002	Winter	3	12	0.0025	8	0.0016	4	0.0008	6	4	2	2.42	1.75	1.00	0.167	0.250	0	93.6	87.5	100
2002	Winter	4	216	0.0024	212	0.0024	4	0.0000	10	7	3	2.38	2.26	1.50	0.942	0.546	0.085	71.6	80.5	94.6
2002	Winter	5	184	0.0046	165	0.0042	19	0.0005	10	6	4	2.61	2.21	1.46	0.710	0.374	0.543	78.6	85.5	72.9
2002	Winter	6	363	0.0034	341	0.0032	22	0.0002	13	7	6	2.68	2.34	2.41	1.02	0.465	0.176	72.3	83.4	93.2
2002	Spring	1	675	0.0013	90	0.0002	585	0.0011	27	8	19	3.62	2.19	3.18	1.13	0.814	1.06	76.1	72.9	74.9
2002	Spring	2	364	0.0012	220	0.0007	144	0.0005	21	8	13	3.58	2.22	3.20	0.815	0.778	0.500	81.4	74.1	86.5
2002	Spring	3	12	0.0014	7	0.0008	5	0.0006	9	5	4	3.02	2.13	1.92	0.148	0.194	0.078	95.3	91.7	96.1
2002	Spring	4	189	0.0026	175	0.0024	14	0.0002	8	6	2	2.49	2.25	0.371	0.510	0.337	0.629	83.0	87.0	37.1
2002	Spring	5	234	0.0031	212	0.0028	22	0.0003	13	8	5	2.54	2.13	1.65	1.16	0.865	0.668	68.6	71.2	71.2
2002	Spring	6	532	0.0031	507	0.0030	25	0.0001	13	7	6	2.48	2.20	2.20	1.22	0.602	0.388	67.0	78.5	85.0
2002	Summer	1	836	0.0018	76	0.0002	760	0.0016	25	6	19	3.62	2.04	3.30	1.02	0.543	0.952	78.0	79.0	77.6
2002	Summer	2	320	0.0015	130	0.0006	190	0.0009	20	6	14	3.57	2.12	2.92	0.754	0.462	0.892	82.5	82.1	76.6
2002	Summer	3	22	0.0015	11	0.0007	11	0.0007	5	4	1	1.91	1.82	0	0.410	1.77	0	82.3	91.2	
2002	Summer	4	526	0.0031	312	0.0018	214	0.0013	13	8	5	2.93	2.43	1.28	0.761	0.565	1.04	79.4	81.2	55.0
2002	Summer	5	285	0.0065	125	0.0029	160	0.0037	14	7	7	2.06	1.81	0.482	1.75	1.00	2.32	54.0	64.6	17.2
2002	Summer	6	600	0.0040	566	0.0038	34	0.0002	13	7	6	2.07	1.74	1.93	1.63	1.06	0.658	56.0	62.1	74.5
2002	Fall	1	1143	0.0019	73	0.0001	1070	0.0018	29	8	21	3.53	2.20	3.26	1.32	0.800	1.14	72.7	73.5	74.1
2002	Fall	2	265	0.0016	179	0.0011	86	0.0005	19	8	11	3.54	2.56	2.81	0.700	0.446	0.646	83.5	85.1	81.3
2002	Fall	3	31	0.0022	25	0.0018	6	0.0004	7	4	3	2.22	1.52	1.46	0.591	0.480	0.126	79.0	76.0	92.1
2002	Fall	4	650	0.0047	228	0.0016	422	0.0031	14	7	7	2.51	2.08	1.31	1.30	0.730	1.50	66.0	74.1	46.5
2002	Fall	5	177	0.0039	167	0.0037	10	0.0002	11	7	4	2.06	1.76	1.57	1.39	1.04	0.429	59.7	62.8	78.5
2002	Fall	6	356	0.0030	346	0.0029	10	0.0001	11	6	5	1.98	1.78	2.12	1.48	0.802	0.200	57.1	69.0	91.4
2003	Winter	1	264	0.0036	36	0.0005	228	0.0031	16	6	10	2.63	2.00	2.07	1.37	0.581	1.26	65.8	77.5	62.2
2003	Winter	2	265	0.0023	187	0.0016	78	0.0007	17	8	9	3.04	2.40	1.60	1.05	0.597	1.57	74.4	80.1	50.4
2003	Winter	4	121	0.0029	121	0.0029	0	0.0000	7	7	0	2.58	2.58		0.223	0.223		92.1	92.1	
2003	Winter	5	104	0.0041	69	0.0027	35	0.0014	12	8	4	2.85	2.50	0.788	0.737	0.495	1.21	79.4	83.5	39.4
2003	Winter	6	299	0.0032	293	0.0031	6	0.0001	9	6	3	2.27	2.14	1.25	0.903	0.442	0.333	71.5	82.9	79.0
2003	Spring	1	375	0.0017	79	0.0004	296	0.0014	23	7	16	3.36	2.23	2.72	1.17	0.581	1.28	74.2	79.3	67.9
2003	Spring	2	262	0.0014	147	0.0008	115	0.0006	20	8	12	3.61	2.47	2.82	0.712	0.535	0.765	83.5	82.2	78.7
2003	Spring	3	21	0.0019	11	0.0010	10	0.0009	4	2	2	1.45	0.439	0.469	0.548	0.561	0.531	72.6	43.9	46.9
2003	Spring	4	233	0.0039	155	0.0026	78	0.0013	11	8	3	2.96	2.48	1.15	0.502	0.517	0.431	85.5	82.8	72.8
2003	Spring	5	172	0.0034	167	0.0033	5	0.0001	10	6	4	2.20	2.02	1.92	1.12	0.569	0.078	66.3	78.0	96.1
2003	Spring	6	293	0.0021	279	0.0020	14	0.0001	12	5	7	2.29	1.98	2.61	1.29	0.337	0.197	63.9	85.5	93.0
2003	Summer	1	306	0.0019	34	0.0002	272	0.0017	20	4	16	3.30	0.57	3.01	1.02	1.43	0.928	76.3	28.5	76.8
2003	Summer	2	85	0.0021	12	0.0003	73	0.0018	13	4	9	2.99	1.61	2.53	0.714	0.386	0.641	80.7	80.7	79.8

Table 2 continued-

H=species diversity; D=divergence from equiprobability; E=evenness

Year	Season	Reach	Overall $N_{individuals}$	Overall relative abundance	Native $N_{individuals}$	Native relative abundance	Introduced $N_{individuals}$	Introduced relative abundance	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
2003	Fall	1	696	0.0021	45	0.0001	651	0.0020	25	5	20	3.25	1.57	3.00	1.39	0.754	4.32	70.0	67.5	69.3
2003	Fall	2	319	0.0018	171	0.0010	148	0.0008	24	8	16	3.62	2.35	2.94	0.964	0.650	1.06	79.0	78.3	73.6
2003	Fall	3	16	0.0026	14	0.0023	2	0.0003	4	3	1	1.50	1.09	0	0.498	0.490	0	75.1	69.1	
2003	Fall	4	330	0.0026	219	0.0018	111	0.0009	12	7	5	2.92	2.25	1.50	0.665	0.553	0.826	81.4	80.3	64.4
2003	Fall	5	73	0.0036	66	0.0033	7	0.0003	8	5	3	2.20	1.78	1.38	0.803	0.541	0.206	73.2	76.7	87.0
2003	Fall	6	319	0.0025	299	0.0024	20	0.0002	11	7	4	2.31	2.00	1.62	1.14	0.804	0.380	67.0	71.4	81.0
2004	Winter	1	344	0.0030	16	0.0001	328	0.0029	19	4	15	2.91	1.70	2.69	1.34	0.297	1.22	68.5	85.1	68.7
2004	Winter	2	136	0.0011	94	0.0008	42	0.0004	20	9	11	3.49	2.47	2.89	0.833	0.702	0.572	80.7	77.8	83.5
2004	Winter	4	127	0.0020	122	0.0019	5	0.0001	10	7	3	2.76	2.57	1.37	0.564	0.242	0.214	83.0	91.4	86.5
2004	Winter	5	148	0.0030	124	0.0025	24	0.0005	15	7	8	3.06	2.45	2.32	0.843	0.362	0.682	78.4	87.1	77.3
2004	Winter	6	214	0.0026	204	0.0024	10	0.0001	12	7	5	2.52	2.25	2.32	1.06	0.560	0	70.4	80.0	100
2004	Spring	1	502	0.0021	91	0.0004	411	0.0017	26	7	19	3.59	2.24	3.05	1.12	0.570	1.20	76.3	79.7	71.8
2004	Spring	2	213	0.0013	81	0.0005	132	0.0008	18	8	10	3.71	2.61	2.84	0.457	0.390	0.478	89.0	87.0	85.6
2004	Spring	3	14	0.0024	14	0.0024	0	0.0000	3	3	0	0.946	0.946		0.639	0.639		59.8	59.8	
2004	Spring	4	176	0.0020	173	0.0020	3	0.0000	11	8	3	2.51	2.39	1.58	0.954	0.605	0	72.4	79.8	100
2004	Spring	5	104	0.0023	90	0.0020	14	0.0003	12	7	5	2.73	2.14	2.27	0.853	0.662	0.051	76.2	76.4	97.8
2004	Spring	6	673	0.0055	354	0.0029	319	0.0026	10	6	4	2.20	2.07	0.248	1.12	0.518	1.75	66.3	80.0	12.4

Table 3. Fish species observations, richness, diversity and abundance by habitat within Reach 1 of the lower Mokelumne River, San Joaquin and Sacramento counties, CA.
H = species diversity; D = divergence from equiprobability; E = eveness

Year	Habitat	Overall $N_{individuals}$	Native $N_{individuals}$	Introduced $N_{individuals}$	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
2000	Confluence (tidal)	310	103	207	18	5	13	3.06	1.39	2.52	1.11	0.93	1.18	73.50	59.80	68.20
2000	Glide (tidal)	239	28	211	9	2	7	2.01	0.97	1.56	1.16	0.03	1.25	63.30	96.70	55.40
2001	Confluence (tidal)	528	68	460	20	7	13	2.48	1.35	2.01	1.84	1.45	1.69	57.40	48.10	54.40
2001	Glide (tidal)	1918	257	1661	33	10	23	3.77	2.32	3.34	1.27	1.01	1.18	74.70	69.70	73.80
2001	Off channel restoration	170	2	168	3	1	2	0.14	0.00	0.05	1.44	0.00	0.95	9.10		5.25
2001	Off-channel (tidal)	225	13	212	19	3	16	3.50	1.46	3.28	0.75	0.13	0.72	82.30	92.00	82.10
2002	Confluence (tidal)	321	86	235	22	6	16	3.78	1.74	3.38	0.68	0.85	0.62	84.70	67.20	84.50
2002	Glide (tidal)	2109	166	1943	33	10	23	3.75	2.67	3.41	1.30	0.65	1.12	74.30	80.40	75.30
2002	Off-channel (tidal)	579	21	558	23	5	18	2.84	1.73	2.65	1.68	0.59	1.52	62.80	74.80	63.50
2003	Confluence (tidal)	248	38	210	20	5	15	3.58	1.61	3.20	0.74	0.71	0.70	82.80	69.30	82.00
2003	Glide (tidal)	1182	138	1044	29	7	22	3.62	2.18	3.22	1.24	0.63	1.24	74.40	77.60	72.10
2003	Off channel restoration	35	8	27	10	2	8	2.49	0.54	2.06	0.83	0.46	0.94	74.90	54.40	68.70
2003	Off-channel (tidal)	176	10	166	16	4	12	3.09	1.85	2.84	0.91	0.15	0.75	77.40	92.30	79.10
2004	Confluence (tidal)	99	31	68	15	4	11	3.47	1.63	3.01	0.43	0.37	0.45	88.90	81.60	86.90
2004	Glide (tidal)	523	61	462	26	7	19	3.46	2.34	3.02	1.24	0.48	1.23	73.60	82.90	71.10
2004	Off channel restoration	21	5	16	9	2	7	2.95	0.97	2.52	0.22	0.03	0.28	92.90	97.10	89.90
2004	Off-channel (tidal)	225	12	213	19	4	15	2.88	1.21	2.66	1.36	0.79	1.25	67.90	60.40	68.10

Table 4. Fish species observations, richness, diversity and abundance by habitat within Reach 2 of the lower Mokelumne River, San Joaquin and Sacramento counties, CA.
H = species diversity; D = divergence from equiprobability; E = eveness

Year	Habitat	Overall $N_{individuals}$	Native $N_{individuals}$	Introduced $N_{individuals}$	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
1998	Confluence (tidal)	123	61	62	19	8	11	3.66	2.47	2.85	0.59	0.53	0.61	86.17	82.24	82.40
1998	Dam basin	3382	3245	137	17	7	10	0.47	0.19	0.96	3.62	2.61	2.37	11.48	6.91	28.77
1998	Glide (tidal)	1256	1223	33	16	8	8	0.81	0.59	2.34	3.19	2.41	0.66	20.16	19.50	77.94
1999	Confluence (tidal)	112	68	44	19	5	14	3.53	2.12	3.26	0.72	0.20	0.55	83.16	91.22	85.57
1999	Dam basin	654	515	139	17	7	10	2.53	1.81	1.71	1.55	1.00	1.61	61.97	64.39	51.44
1999	Glide (tidal)	174	122	52	15	7	8	2.79	2.19	1.25	1.12	0.62	1.75	71.43	78.04	41.77
2000	Confluence (tidal)	279	150	129	22	6	16	3.50	1.83	3.29	0.96	0.75	0.71	78.52	70.90	82.20
2000	Dam basin	267	193	74	16	7	9	2.90	2.28	1.45	1.10	0.53	1.72	72.48	81.11	45.73
2000	Glide (tidal)	203	179	24	19	8	11	3.07	2.46	3.23	1.17	0.54	0.23	72.37	81.98	93.24
2001	Confluence (tidal)	1749	91	1658	24	7	17	1.72	1.98	1.40	2.86	0.83	2.69	37.62	70.37	34.24
2001	Dam basin	375	269	106	19	7	12	3.23	2.42	2.25	1.02	0.39	1.34	75.98	86.06	62.73
2001	Glide (tidal)	437	397	40	21	9	12	3.19	2.71	3.14	1.20	0.46	0.44	72.69	85.84	87.66
2002	Confluence (tidal)	222	28	194	18	5	13	3.29	1.44	2.93	0.88	0.88	0.77	78.79	61.96	79.08
2002	Dam basin	472	296	176	20	8	12	3.27	2.31	2.33	1.05	0.69	1.25	75.66	76.92	65.08
2002	Glide (tidal)	419	327	92	19	7	12	3.08	2.05	3.28	1.17	0.76	0.31	72.41	72.92	91.36
2003	Confluence (tidal)	295	39	256	20	6	14	2.81	1.95	2.29	1.51	0.64	1.52	64.99	75.26	60.18
2003	Dam basin	317	238	79	20	7	13	3.19	2.21	2.89	1.13	0.59	0.81	73.90	78.89	78.17
2003	Glide (tidal)	311	236	75	19	8	11	3.48	2.63	2.85	0.77	0.37	0.61	81.90	87.63	82.35
2004	Confluence (tidal)	113	22	91	16	5	11	3.29	1.71	2.79	0.71	0.61	0.67	82.30	73.56	80.71
2004	Dam basin	129	88	41	14	8	6	3.40	2.69	2.08	0.41	0.31	0.51	89.25	89.69	80.39
2004	Glide (tidal)	107	65	42	17	8	9	3.59	2.66	2.57	0.49	0.34	0.60	87.92	88.81	81.08

Table 5. Fish species observations, richness, diversity and abundance by habitat within Reach 3 of the lower Mokelumne River, San Joaquin County, CA.
H = species diversity; D = divergence from equiprobability; E = eveness

Year	Habitat	Overall $N_{individuals}$	Native $N_{individuals}$	Introduced $N_{individuals}$	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
1997	Lake		2			1										
1998	Lake	81	70	11	10	5	5	2.07	1.38	2.23	1.25	0.94	0.09	62.24	59.38	96.10
1999	Lake	64	60	4	10	7	3	2.64	2.36	1.50	0.68	0.45	0.08	79.56	84.04	94.64
2000	Lake	56	49	7	7	4	3	1.70	1.13	1.38	1.10	0.87	0.21	60.71	56.48	86.99
2001	Lake	63	55	8	9	5	4	2.59	2.11	1.55	0.58	0.21	0.45	81.70	90.97	77.44
2002	Lake	51	26	77	6	6	12	2.03	2.07	2.97	0.55	0.52	0.62	78.67	79.96	82.78
2003	Lake	28	25	3	6	4	2	2.08	1.67	0.92	0.51	0.33	0.08	80.37	83.32	91.83
2004	Lake	14	14	0	3	3	0	0.95	0.95		0.64	0.64		59.71	59.71	

Table 6. Fish species observations, richness, diversity and abundance by habitat within Reach 4 of the lower Mokelumne River, San Joaquin Count7, CA.
H = species diversity; D = divergence from equiprobability; E = eveness

Year	Habitat	Overall $N_{individuals}$	Native $N_{individuals}$	Introduced $N_{individuals}$	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
1997	Glide	40	28	12	9	4	5	2.71	1.78	1.95	0.46	0.22	0.37	85.50	88.83	84.02
1997	Glide (LWD)	115	78	37	11	7	4	2.42	1.87	0.76	1.04	0.94	1.24	69.90	66.62	37.83
1998	Glide	171	141	30	8	7	1	2.60	2.34	0.00	0.40	0.47	0.00	86.56	83.23	
1998	Glide (LWD)	224	209	15	13	7	6	2.62	2.26	2.42	1.08	0.55	0.16	70.87	80.39	93.72
1998	Run	145	140	5	10	6	4	2.38	2.17	1.92	0.94	0.41	0.08	71.64	84.03	96.10
1999	Glide	209	209		5	5	0	1.74	1.74		0.59	0.59		74.77	74.77	
1999	Glide (LWD)	298	297	1	7	6	1	2.28	2.25		0.53	0.33		81.07	87.09	
1999	Run	177	177		5	5	0	2.29	2.29		0.03	0.03		98.73	98.73	
2000	Off-channel contiguous pool	127	116	11	9	5	4	1.35	0.84	1.79	1.82	1.48	0.21	42.55	36.24	89.50
2000	Glide	213	201	12	9	6	3	1.54	1.23	1.19	1.63	1.35	0.40	48.67	47.68	75.00
2000	Glide (LWD)	479	390	89	9	7	2	2.15	1.77	0.09	1.02	1.03	0.91	67.92	63.16	8.89
2000	Off-channel contiguous pool	316	34	282	10	7	3	1.06	2.22	0.37	2.26	0.59	1.22	31.92	78.91	23.29
2000	Run	184	183		7	6	1	1.83	1.79		0.97	0.79		65.30	69.41	
2001	Off-channel contiguous pool	467	32	435	13	6	7	1.46	2.16	1.02	2.24	0.42	1.79	39.34	83.65	36.23
2001	Glide	274	206	68	14	8	6	2.49	1.87	1.09	1.32	1.13	1.49	65.30	62.35	42.34
2001	Glide (LWD)	427	411	16	13	8	5	2.50	2.28	2.18	1.20	0.72	0.14	67.64	75.87	93.89
2001	Run	312	312		6	6	0	1.94	1.94		0.64	0.64		75.12	75.12	
2002	Off-channel contiguous pool	525	32	493	10	4	6	1.64	1.43	1.30	1.68	0.57	1.29	49.33	71.71	50.27
2002	Glide	382	278	104	14	8	6	2.59	2.20	0.56	1.21	0.80	2.03	68.12	73.17	21.55
2002	Glide (LWD)	396	340	56	12	8	4	2.72	2.35	0.84	0.86	0.65	1.16	75.98	78.31	42.08
2002	Run	278	277	1	8	7	1	2.54	2.52		0.46	0.29		84.73	89.64	
2003	Off-channel contiguous pool	193	47	146	9	5	4	2.30	1.87	1.38	0.87	0.46	0.62	72.48	80.35	68.91
2003	Glide	133	106	27	11	8	3	2.65	2.26	0.61	0.81	0.74	0.98	76.62	75.28	38.19
2003	Glide (LWD)	217	202	15	9	8	1	2.80	2.61		0.37	0.39		88.23	87.16	
2003	Run	141	140	1	8	7	1	2.47	2.42		0.53	0.38		82.28	86.38	
2004	Off-channel contiguous pool	7	5	2	4	2	2	1.84	0.97	1.00	0.16	0.03	0.00	92.12	97.10	100.00
2004	Glide	107	104	3	10	8	2	2.61	2.46		0.72	0.54		78.43	82.14	
2004	Glide (LWD)	94	94		6	6	0	1.99	1.99		0.60	0.60		76.95	76.95	
2004	Off-channel contiguous pool	3		3	1		1									
2004	Run	92	92	0	7	7	0	2.37	2.37		0.44	0.44		84.30	84.30	

Table 7. Fish species observations, richness, diversity and abundance by habitat within Reach 5 of the lower Mokelumne River, San Joaquin County, CA.
H = species diversity; D = divergence from equiprobability; E = eveness

River Reach	Habitat	Overall $N_{individuals}$	Native $N_{individuals}$	Introduced $N_{individuals}$	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
1997	Glide	178	178		5	5		1.53	1.53		0.77	0.77		66.95	66.95	
1997	Run	126	126		3	3		0.48	0.48		1.11	1.11		30.10	30.10	
1997	Split-channel															
1997	Split-channel run	126	126		3	3		0.48	0.48		1.11	1.11		30.10	30.10	
1997	Split-channel riffle	17	17		1	1										
1998	Glide	57	55	2	7	6	1	2.13	1.98	0.00	0.68	0.61	0.00	75.83	76.55	
1998	Run	49	49		3	3		0.39	0.39		1.20	1.20		24.51	24.51	
1998	Split-channel	157	156	1	6	5	1	2.18	2.14	0.00	0.41	0.18	0.00	84.31	92.05	
1999	Glide	191	188	3	7	4	3	1.40	1.28	1.58	1.41	0.72	0.00	49.95	64.04	100.00
1999	Split-channel	177	176	1	6	5	1	2.16	2.12	0.00	0.42	0.20		83.67	91.50	
1999	Split-channel run	26	26		4	4		1.46	1.46		0.54	0.54		73.02	73.02	
2000	Off-channel contiguous pool	158	145	13	8	4	4	1.92	1.50	1.55	1.08	0.50	0.45	63.89	75.14	77.33
2000	Glide	441	441		5	5		0.94	0.94		1.39	1.39		40.31	40.31	
2000	Run	49	49		3	3		1.58	1.58		0.01	0.01		99.50	99.50	
2000	Split-channel	300	299	1	7	6	1	2.00	1.98		0.80	0.61		71.34	76.48	
2001	Glide	512	507	5	11	8	3	1.09	1.73	1.52	1.65	1.27	0.06	52.18	57.60	96.02
2001	Run	216	216		4	4		0.35	0.35		1.65	1.65		17.75	17.75	
2001	Split-channel	308	314	4	8	6	2	2.53	2.45	0.81	0.47	0.13	0.19	84.29	94.86	81.13
2001	Split-channel run															
2002	Off-channel contiguous pool	264	74	190	13	6	7	1.90	1.82	0.74	1.80	0.77	2.07	51.22	70.29	26.25
2002	Glide	303	291	12	13	7	6	1.80	1.52	2.36	1.90	1.28	0.23	48.54	54.24	91.12
2002	Run	253	234	19	7	5	2	1.23	0.89	0.49	1.57	1.43	0.51	43.94	38.49	48.55
2002	Split-channel	313	304	9	8	6	2	2.24	2.09	0.99	0.76	0.50	0.01	74.78	80.72	99.11
2002	Split-channel run	130	130		7	7		2.13			0.68			75.82		
2003	Off-channel contiguous pool	43	1	42	5	1	4	1.03		0.89	1.29		1.11	44.36		47.13
2003	Glide	124	123	1	8	7	1	2.07	2.02		0.93	0.79		69.03	71.94	
2003	Run	62	61	1	4	3	1	0.67	0.56		1.33	1.02		33.61	35.47	
2003	Split-channel	182	178	4	9	6	3	2.38	2.24	1.50	0.79	0.34	0.09	75.07	86.80	94.64
2003	Split-channel run	181	181		6	6		1.56	1.56		1.02	1.02		60.35	60.35	
2004	Off-channel contiguous pool	62	21	41	15	4	11	3.70	1.88	3.23	0.21	0.12	0.22	94.73	94.21	93.50
2004	Glide	122	104	18	11	7	4	2.88	2.48	1.10	0.58	0.33	0.90 ##	88.23	54.88	
2004	Run	53	53		4	4		0.50	0.50		1.50	1.50		24.96	24.96	
2004	Split-channel	89	89		6	6		2.22	2.22		0.37	0.37		85.86	85.86	
1997	Riffle	17	17		1	1										
2004	Split-channel run	39	39		3	3		0.68	0.68		0.91	0.91		42.71	42.71	

Table 8. Fish species observations, richness, diversity and abundance by habitat within Reach 6 of the lower Mokelumne River, San Joaquin County, CA.
H = species diversity; D = divergence from equiprobability; E = eveness

River Reach	Habitat	Overall $N_{individuals}$	Native $N_{individuals}$	Introduced $N_{individuals}$	Overall $N_{species}$	Native $N_{species}$	Introduced $N_{species}$	Overall H	Native H	Introduced H	Overall D	Native D	Introduced D	Overall E	Native E	Introduced E
1997	Glide		19			3			0.59			0.99			37.27	
1997	Off channel non-contiguous pool	56	56	0.9041	3	3		0.16	0.16		0.90	0.90		57.04	57.04	
1997	Off-channel contiguous pool	203	153	50	17	7	10	2.89	1.86	2.77	1.20	0.94	0.56	70.75	66.42	83.27
1997	Pool		101			4			1.70			0.30			85.16	
1997	Riffle	520	519	1	4	3	1	0.45	0.45		1.55	1.55		22.54	22.54	
1997	Run		219			5			1.91			0.41			82.45	
1997	Side-channel riffle	317	316	1	4	3	1	0.61	0.58		1.39	1.00		30.56	36.74	
1997	Split-channel run	92	90	2	5	4	1	1.28	1.15		1.05	0.85	0.00	54.95	57.49	
1998	Glide	63	62	1	5	4	1	1.91	1.82		0.41	0.18	0.00	82.21	91.01	
1998	Off-channel contiguous pool	232	148	84	16	5	11	2.97	1.75	2.51	1.03	0.58	0.95	74.16	75.22	72.47
1998	Pool	65	56	9	10	6	4	2.47	1.91	1.75	0.85	0.67	0.25	74.33	73.92	87.64
1998	Riffle	115	115		2	2		0.13	0.13		0.87	0.87		12.65	12.65	
1998	Run	178	177	1	6	5	1	1.96	1.92		0.63	0.41	0.00	75.68	82.56	
1998	Side-channel riffle	35	35		1	1										
1998	Split-channel run	253	252	1	7	6	1	1.75	1.72		1.06	0.87		62.19	66.36	
1999	Off-channel contiguous pool	544	465	79	14	6	8	2.64	1.94	2.62	1.17	0.64	0.38	69.32	75.17	87.34
1999	Pool	330	324	6	8	4	4	1.47	1.33	1.79	1.53	0.67	0.21	48.87	66.32	89.62
1999	Riffle	5	5		1	1										
1999	Run	564	564		4	4		1.67	1.67		0.33	0.33		83.50	83.50	
1999	Side-channel riffle	133	133		2	2		0.06	0.06		0.94	0.94		6.39	6.39	
1999	Split-channel run	325	325		5	5		1.61	1.61		0.70	0.70		69.53	69.53	
1999	Split-channel riffle	28	28		2	2		0.22	0.22		0.78	0.78		22.23	22.23	
1999	Glide	218	218		4	4		1.72	1.72		0.28	0.28		85.99	85.99	
2000	Off-channel contiguous pool	1096	904	192	13	5	8	2.31	1.69	1.42	1.39	0.63	1.58	62.46	72.71	47.41
2000	Pool	110	110		4	4		0.98	0.98		1.02	1.02		49.20	49.20	
2000	Riffle	117	117		3	3		0.60	0.60		0.99	0.99		37.80	37.80	
2000	Run	405	405		4	4		1.82	1.82		0.18	0.18		91.15	91.15	
2000	Side-channel riffle	37	37		1	1										
2000	Split-channel run	358	358		5	5		1.48	1.48		0.84	0.84		63.62	63.62	
2000	Glide	196	196		5	5		1.82	1.82		0.50	0.50		78.29	78.29	
2001	Off-channel contiguous pool	475	398	77	15	5	10	2.78	2.05	2.62	1.13	0.27	0.70	71.20	88.29	78.89
2001	Pool	337	333	4	10	6	4	1.83	1.73	2.00	1.49	0.85	0.00	55.11	67.10	100.00
2001	Riffle	479	479		3	3		0.36	0.36		1.22	1.22		23.00	23.00	
2001	Run	645	642	3	9	6	3	1.92	1.88	1.59	1.25	0.70	0.00	60.63	72.75	100.00
2001	Side-channel riffle	46	46		2	2		0.15	0.15		0.85	0.85		15.11	15.11	
2001	Split-channel run	317	316	1	6	5	1	1.94	1.91		0.65	0.41		74.93	74.93	
2001	Split-channel riffle	78	78		4	4		1.03	1.03		0.97	0.97		51.75	51.75	
2001	Glide	412	409	3	7	6	1	1.79	1.74		1.01	0.84		63.90	67.48	
2001	Off-channel contiguous pool	475	398	77	15	5	10	2.78	2.05	2.62	1.13	0.27	0.70	71.20	88.29	78.89
2002	Riffle	368	368		3	3		0.24	0.24		1.35	1.35		15.10	15.10	
2002	Side-channel riffle	43	40	3	4	3	1	1.78	1.52		0.22	0.07		88.94	95.88	
2002	Split-channel run	261	260	1	5	4	1	1.33	1.30		0.99	0.70		57.37	65.04	
2002	Split-channel run	72	72		1	1										
2002	Dam Basin	106	102	4	6	4	2	2.00	1.81	0.81	0.59	0.19	0.19	77.35	90.26	81.13
2002	Glide	244	239	5	7	6	1	1.95	1.85		0.86	0.74		69.52	71.39	
2002	Off-channel contiguous pool	291	236	55	11	6	5	2.50	1.85	1.59	0.96	0.73	0.73	72.32	71.65	68.42
2002	Pool	358	347	11	12	7	5	2.03	1.82	2.30	1.55	0.99	0.02	56.72	64.85	99.05
2003	Run	348	340	8	11	7	4	2.13	1.98	1.55	1.33	0.82	0.45	61.63	70.68	77.44
2003	Split-channel run	104	104	0	5	5		1.94	1.94		0.38	0.38		83.71	83.71	
2003	Off-channel contiguous pool	139	117	22	9	5	4	2.43	1.82	1.69	0.74	0.50	0.31	76.74	78.58	84.29
2003	Pool	140	131	9	11	6	5	2.33	1.97	2.20	1.13	0.61	0.12	67.39	76.31	94.63
2003	Riffle	333	333		3	3		1.30	1.30		0.29	0.29		81.79	81.79	
2004	Side-channel riffle	88	81	7	4	3	1	1.32	0.99		0.68	0.59		65.80	62.74	
2004	Split-channel run	69	69		4	4		1.57	1.57		0.43	0.43		78.72	78.72	
2004	Split-channel riffle	25	25		2	2		0.72	0.72		0.28	0.28		72.19	72.19	
2004	Glide	79	77	2	6	5	1	1.81	1.68		0.78	0.64		69.97	72.39	
2004	Off-channel contiguous pool	482	166	316	10	6	4	1.80	2.18	0.18	1.52	0.41	1.81	54.17	84.23	9.20
2004	Pool	60	56	4	9	6	3	2.51	2.20	1.50	0.66	0.39	0.08	79.03	85.05	94.64
2004	Riffle	149	149		3	3		0.75	0.75		0.83	0.83		47.52	47.52	
2004	Run	190	190		5	5		2.04	2.04							
2004	Side-channel riffle	250	247	3	6	4	2	1.12	1.02	0.92	1.47	0.98	0.08	43.15	51.14	91.83