APPENDIX E

Fish Populations of Mammoth Creek, Mono County, California (1988-2008)

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FISH POPULATIONS OF MAMMOTH CREEK
MONO COUNTY, CALIFORNIA (1988 – 2008)

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Fish Populations of Mammoth Creek
Mono County, California (1988 – 2008)

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ACKNOWLEDGEMENTS

We acknowledge and thank the authors of the 17 annual fish community survey reports conducted since 1988 including: Bratovich et al. 1990; Hood et al. 1992, 1993, 1994; Jenkins and Dawson 1996, 1997; Hood 1998; Jenkins 1999; Hood 2001, 2002, 2003, 2004, 2006a, 2006b; and in particular Salamunovich (2006, 2007, 2009), who provided very useful, updated information on Mammoth Creek and its fish communities. Special thanks are extended to Mammoth Community Water District and its General Manager, Mr. Greg Norby.

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Fish Populations of Mammoth Creek Mono County, California (1988 – 2008)

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Fish Populations of Mammoth Creek, Mono County, California (1988 – 2008)

1.0 INTRODUCTION

Instream flow needs for the fish populations in Mammoth Creek, Mono County, California have been the focus of several investigations since the 1970's. As a result of these investigations, various bypass flow schedules have been developed for the purpose of sustaining the aquatic habitat and fishery resources in Mammoth Creek.

The objectives of this report are to summarize the results of the fisheries investigations that have been conducted since 1988, examine potential temporal trends in abundance, and evaluate potential relationships between fish population abundance and flows in Mammoth Creek.

2.0 REGIONAL SETTING/BACKGROUND

Mammoth Creek originates high in the southern Sierra Nevada, and is one of several creeks that flow into the Mammoth Lakes Basin. The Mammoth Lakes Basin is a popular outdoor recreation area located in Mono County, California, ranging in elevation from about 11,000 feet in the headwaters along the Mammoth Crest to about 7,000 feet at the confluence of Mammoth and Hot creeks, with a drainage area of about 71 square miles (DWR 1973).

Mammoth Creek drains the Mammoth Lakes Basin, flows through the Town of Mammoth Lakes, and discharges into Hot Creek (**Figure E-1**). Mammoth Creek is part of the Owens Subprovince of the Great Basin Province (Moyle 2002). Historically, trout are believed to have not been present in the Owens River watershed, including the Mammoth Lakes Basin. Moyle et al. (1996) suggested that native fishes in the Owens River Basin, with the exception of the Owens sucker, generally did not occur in streams above 4,900 feet in elevation. Fishes native to the regional setting include Owens sucker (*Catostomus fumeiventris*) and Owens tui chub (*Gila bicolor snyderi*), both of which are presently found in the lower reaches of Mammoth Creek.

Presently, Mammoth Creek supports brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) along much of its length. It is unknown when rainbow trout were introduced into the Mammoth Lakes Basin, but Jenkins et al. (1999) suggested that brown trout were probably introduced into the basin in the 1890's. In the past, the California Department of Fish and Game (CDFG) planted brown trout from the Hot Creek Hatchery into Mammoth Creek, although brown trout have not been planted in the creek since 1982. The CDFG also annually planted rainbow trout from the Hot Creek Hatchery into Mammoth Creek until 2007, then shifted the planting of rainbow trout into Mammoth Creek to stocks from the Mount Whitney Hatchery. Naturalized populations of rainbow trout and brown trout presently occur in Mammoth Creek.

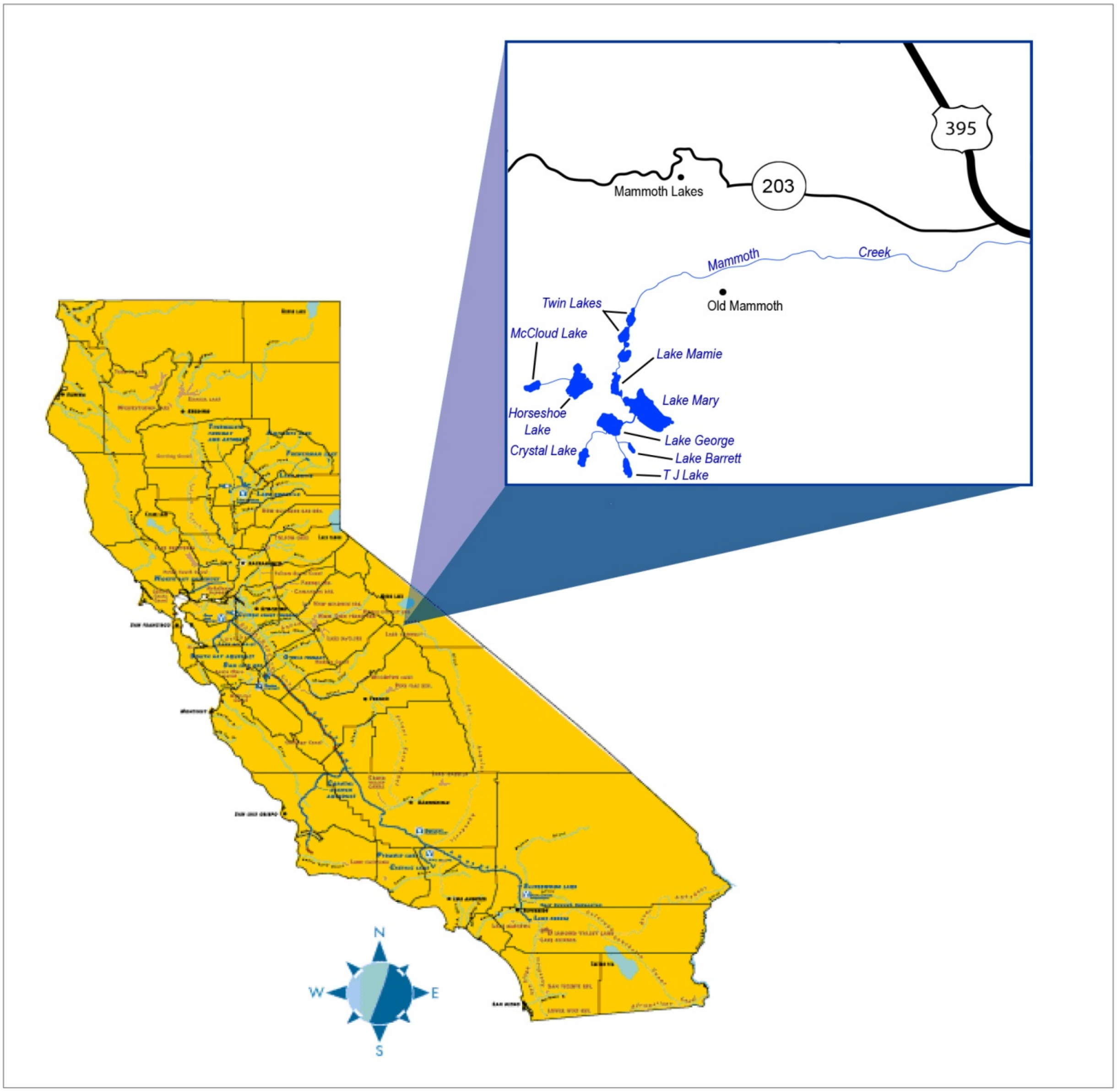

Figure E-1. Mammoth Creek, Mono County, California.

3.0 EXPERIMENTAL DESIGN AND SAMPLING

Extensive evaluations of Mammoth Creek and its fish resources were initiated in 1988. The experimental design and rationale for the original selection of the fish survey sample sites are described in Bratovich et al. (1990). They established the Mammoth Creek study area as extending from Lake Mary downstream to the confluence of Mammoth Creek and Hot Creek, a distance of approximately 10.4 miles. Five distinct reaches were identified in Mammoth Creek, based upon analysis of topographic maps, calculation of gradient profiles, and visual inspection of the creek and associated morphological characteristics, tributaries, riparian vegetation and surrounding topography. Four of these reaches were located in the lower 8.9 miles (86.3

percent of the entire length) of the creek, and were characterized by gradients that range from 0.7 to 3.8 percent. By contrast, a fifth reach comprised of the upper 1.4 miles (13.7 percent of the creek) was characterized by a gradient of approximately 12.3 percent. Habitat in this high-gradient reach (Reach A) typically consisted of a cascade-plunge pool sequence in which the amount of usable fish habitat was not determined by stream discharge, but by sectional (streambed rock) hydraulic controls. Habitat characterization and all subsequent investigations, including fish surveys, were restricted to the remaining four study reaches (Reaches B, C, D and E). Thus, the fish survey project area consists of the lower 8.9 miles of Mammoth Creek from the Sherwin Street crossing in the Town of Mammoth Lakes downstream to Mammoth Creek's confluence with Hot Creek.

Aquatic habitat characteristics vary considerably among the four study reaches based upon the combination of channel morphology, riparian vegetation, stream gradient, and bed substrate size and composition. Channel braiding occurs in each study reach apparently associated with large woody debris accumulation in lower gradients sections of the channel (Bratovich et al. 1990).

Distinct differences in the amounts of riparian cover within each study reach were observed during the habitat mapping survey conducted in 1988 (Bratovich et al. 1990). To ensure representation of riparian cover and dispersion of sampling sections, fish sampling stations were originally located within "high" and "low" density riparian habitat sites within each study reach. Each sampling site was identified by a two-letter code, with the first letter indicating the reach (B, C, D, or E) and the second letter indicating a "high" (H) or "low" (L) density riparian characterization.

Fish community surveys were conducted with a relatively consistent sampling methodology in 1988, 1992 through 1997, and 1999 through 2008. Several entities have been involved in the collection and reporting, including Beak Consultants in 1988 and 1992-1994, UC SNARL in 1995 and 1996, Horseshoe Canyon Biological Consultants in 1999, KDH in 1997 and 2000-2005, and Thomas R. Payne and Associates in 2006-2008.

The data used in this report were obtained from the fish community surveys performed in Mammoth Creek in 1988, 1992-1997 and 1999-2008. During these fish community surveys four contiguous reaches (i.e., Reaches B through E) were sampled **(Figure E-2)**.

Each surveyed reach contained two sampling sites that were approximately 300-ft long[1], one catalogued as having high riparian cover (i.e., H), and the other as having low riparian cover (i.e., L). The location of H and L sites were selected randomly in 1988 and 1992. Approximately the same 1992 site locations were sampled in subsequent years. **Table E-1** displays the limits, length and number of potential sample sites per reach, and the number of H and L sites electrofished each year.

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[1] During the 1988 survey the electrofishing sites were approximately 100-ft long instead of 300-ft long. Except for the 2006, 2007 and 2008 surveys, the exact lengths of the annually sampled sites were not reported. In 2006, the length of the eight sampled sites averaged 299.6 ft with a standard error of 12.3 ft, in 2007 they averaged 304.9 ft with a standard error of 14.2 ft, and in 2008 they averaged 308.5 ft with a standard error of 12.5 ft.

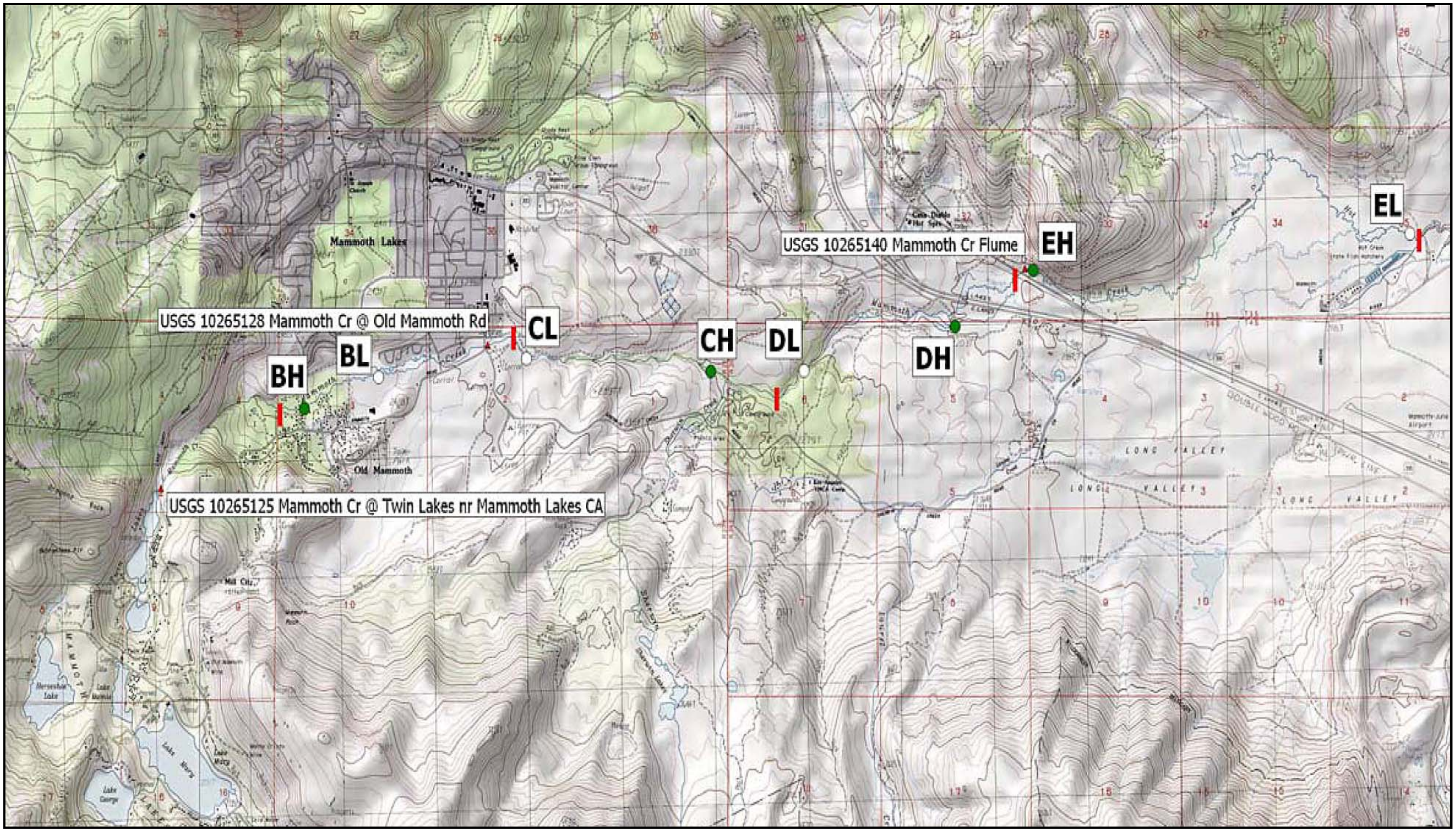

Figure E-2. The Mammoth Creek Basin and location of the eight fish sampling sites. Red hashes indicate reach boundaries. Green dots represent high riparian density fish samples sites, and white dots represent low riparian density sites. Red triangles identify stream flow gage locations.

Table E-1. Mammoth Creek fish community survey sample site characteristics.

Reach	B		C		D		E		Total	
Upstream Reach Limit	Sherwin St.		Canyon head		Sherwin Creek footbridge		Hwy 395 bridge		Sherwin St.	
Downstream Reach Limit	Canyon head		Sherwin Creek footbridge		Hwy 395 bridge		Hot Creek		Hot Creek	
Reach Length (ft)	9,842		8,661		9,055		19,685		47,243	
1988 Sampling Site Length (ft)	100		100		100		100		100	
1992-2005 Sampling Site Lengths (ft)	300		300		300		300		300	
Measured 2006 Sampling Site Lengths (ft)	303	287	300	309	320	294	281	303	301	298
Measured 2007 Sampling Site Lengths (ft)	303	289	306	318	326	296	286	315	305	305
Measured 2008 Sampling Site Lengths (ft)	308	306	306	318	333	295	294	308	310	307
Potential 1988 Sampling Sites (N)	98		87		91		197		473	
Potential 1992-2008 Sampling Sites (N)	33		29		30		66		158	
Sites Annually Sampled per Reach Riparian Category	H	L	H	L	H	L	H	L	H	L
Nov. 2-4, 1988	1	1	1	1	1	1	1	1	4	4
Oct. 21-28, 1992	1	1	1	1	1	1	1	1	4	4
Oct. 12-19, 1993	1	1	1	1	1	1	1	1	4	4
Oct. 4-11, 1994	1	1	1	1	1	1	1	1	4	4
Nov. 1-7, 1995	1	1	1	1	1	1	1	1	4	4
Oct. 3-8, 1996	1	1	1	1	1	1	1	1	4	4
Oct. 4-10, 1997	1	1	1	1	1	1	1	1	4	4
Sep. 24-29, 1999	1	1	1	1	1	1	1	1	4	4
Oct. 10-15, 2000	1	1	1	1	1	1	1	1	4	4
Oct. 9-13, 2001	1	1	1	1	1	1	1	1	4	4
Sep. 30 - Oct. 3, 2002	1	1	1	1	1	1	1	1	4	4
Sep. 29 - Oct. 3, 2003	1	1	1	1	1	1	1	1	4	4
Oct. 4-8, 2004	1	1	1	1	1	1	1	1	4	4
Sep. 30 - Oct. 5, 2005	1	1	1	1	1	1	1	1	4	4
Oct. 11 -15, 2006	1	1	1	1	1	1	1	1	4	4
Oct. 10 -14, 2007	1	1	1	1	1	1	1	1	4	4
Oct. 8 -11, 2008	1	1	1	1	1	1	1	1	4	4

During the 17 annual fall surveys, fish were collected at each sampling site by electrofishing with a multiple-pass removal method. Three complete passes were normally conducted at each sampling site. Prior to electrofishing, the upstream and downstream boundaries of selected sampling sites were identified with rebar driven into each bank. On the day of sampling, sites were closed using 0.25-inch mesh block nets placed simultaneously across the upstream and downstream boundaries, using the rebar as anchors. A good description of field sampling methodologies is provided in Salamunovich (2006).

Over the years, several of the sample sites have been moved up or downstream due to changes in landowner access or channel morphology, although the habitat areas have remained unchanged (Hood 2006b). In the 2006 - 2008 surveys, the site locations sampled were almost identical to those sampled in October 2005, and were easily identified by flagging and rebar left behind from previous surveys (Salamunovich 2006, 2007, 2009). Although sample site locations have remained relatively consistent, riparian cover has changed since establishment of the sample sites in 1988. In addition, the relative density characterization of "high" or "low" varies among reaches. For example, KDH in their 1997, 2000 and 2004 Mammoth Creek Fish Community Survey reports mention that "*site EH represents a zone of high riparian cover within reach E*" but "*in comparison with other high riparian cover sites, it is characterized by a relatively low amount of riparian cover*". KDH also mentioned that site BL has changed over time by willow tree cover establishments, resulting in increased riparian cover.

Salamunovich (2006) correctly states that … "*Discretion must be used when comparing and interpreting the results between high and low-density riparian cover sites because of between reach variation in riparian density and tree species and changes in the riparian area over time.*" Appropriately, the high and low riparian cover categories were not utilized as strata in the inter-annual trend analyses presented in this report because of among-reach differences in the relative amount of riparian cover required for a site to be classified as high or low cover, and because of site-specific changes in the amount of riparian cover over time.

The 17 annual surveys have shown that the species composition at Mammoth Creek consists primarily of brown trout (*Salmo trutta*), an introduced species that is now naturally reproducing in the creek and that, year-after-year, has generally represented at least 50 percent of the catch collected in the annual electrofishing surveys.

Rainbow trout (*Oncorhynchus mykiss*) is the second most abundant salmonid species in Mammoth Creek, but its numbers rarely exceed 30 percent of the catch collected in the annual electrofishing surveys. This species is represented by naturally reproducing descendants from hatchery rainbow trout planted in past years, as well as by hatchery rainbow trout planted during each survey year. Numbers of other salmonids such as brook trout (*Salvelinus fontinalis*) are rare. The most common non-salmonid species present in the creek are Owens tui chub (*Gila bicolor*) and Owens sucker (*Catostomus fumeiventris*).

4.0 DATA ANALYSIS

4.1 STANDARDIZED FISH ABUNDANCE

The population estimates and sample site lengths were used to extrapolate the population numbers to indices of fish abundance, expressed as the number of fish per mile in Mammoth

Creek. The standardized abundance estimates (trout/mile) were calculated for both brown and "wild" rainbow trout for each of the sample sites for each of the 17 years included in the analysis. Average standardized estimates for both brown and "wild" rainbow trout were calculated annually, and for the overall 17-year period. Because population estimation using a multiple-pass depletion estimator was not possible for Owens sucker and tui chub due to relatively low numbers of fish captured, their abundance was calculated as total catch/site length, then expressed as fish/mile.

4.2 TROUT LENGTH-FREQUENCY

Fork lengths of "wild" and hatchery rainbow trout collected in Mammoth Creek were examined as reported by the various investigators over the 17-year period of record. For brown trout, the fork lengths of all brown trout captured over the 17-year period of record were used to determine the upper fork length limit for young-of-the-year (YOY). The fork lengths (mm) of all brown trout caught through electrofishing in each reach over the 17 annual surveys were used to construct histograms with 1-cm bins (**Figure E-3**). Inspection of these histograms indicates that the upper fork length limit for YOY brown trout was 119 mm. Consequently, the annual brown trout survey data were revisited to separate all brown trout with fork lengths less than 120 mm. The resulting data subsets were considered YOY brown trout, and were used to estimate their abundance and variance per sample site each year, with the aid of *Microfish 3.0 for Windows* (**Table E-2**).

4.3 INTER-ANNUAL ABUNDANCE TRENDS

The examination of rainbow trout temporal (inter-annual) trends and potential relationships between abundance and flows in Mammoth Creek is problematic for several reasons. First, physiologic characteristics such as frayed fins, deformed fins, missing adipose fins, or abraded skin on snouts or backs are not consistently reliable indicators of hatchery origin, and classifying fish as "wild" if they do not display those physiologic characteristics also may not be accurate. Also, several different investigators (and field crews) have conducted the annual surveys over the years, and it is not possible to evaluate the consistency of visual physiologic examination and application for hatchery origin determination.

Second, the planting of rainbow trout by the CDFG into Mammoth Creek to support a recreational "put-and-take" fishery confounds the ability to examine inter-annual trends and potential relationships between abundance and flow. In past years, the location, timing and number of rainbow trout planted in Mammoth Creek annually are not readily discernable. In recent years (2004–2008), the number of rainbow trout planted in Mammoth Creek has ranged from an estimated 6,917 to 14,583 fish annually, at 12 to 15 different locations along the creek, about once a week throughout the April-October trout fishing season (**Table E-3**) (Salamunovich 2009). Thus, plantings of rainbow trout in Mammoth Creek have actually occurred when the annual fish surveys were being conducted.

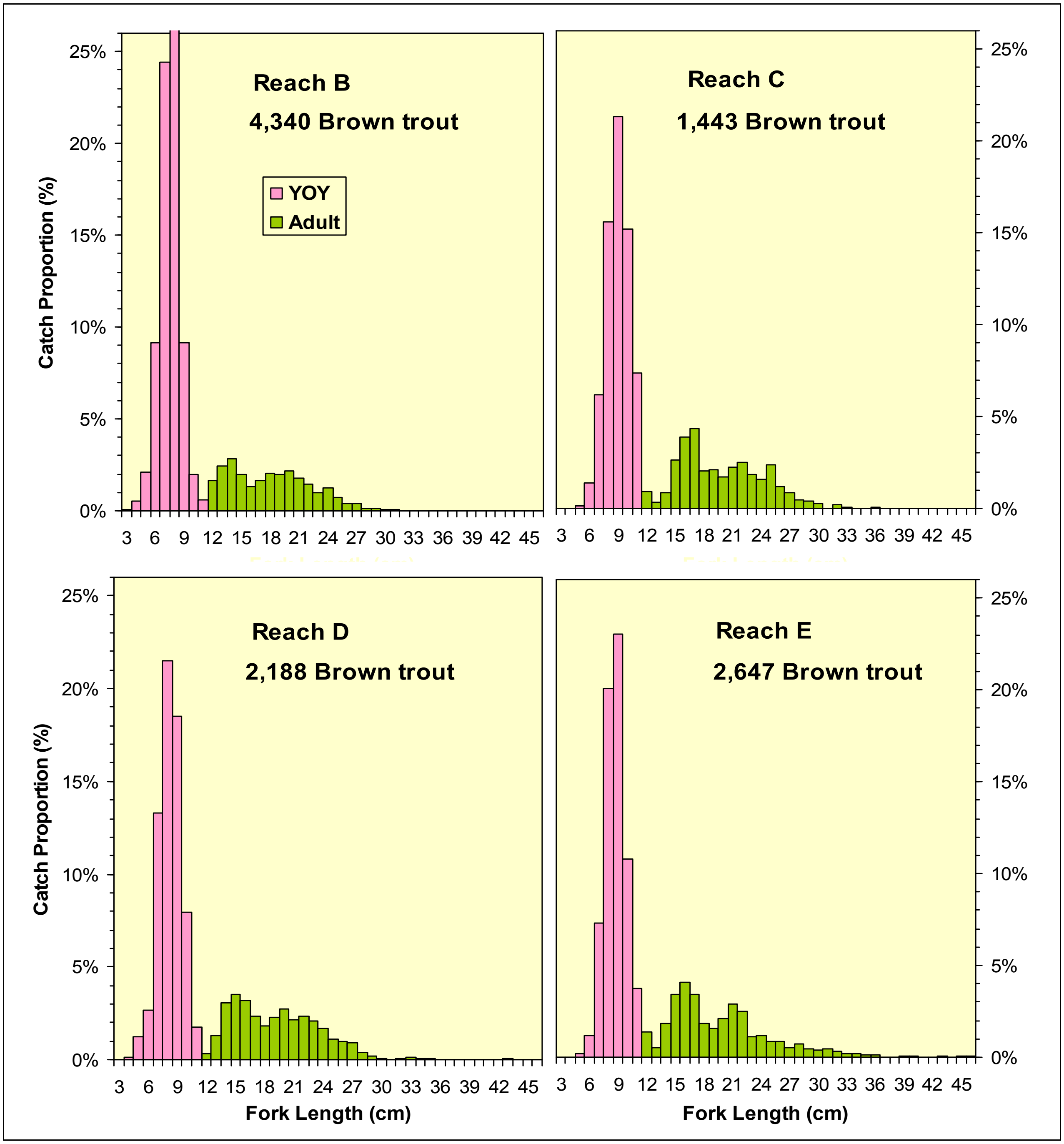

Figure E-3. Length distributions of brown trout captured at Reaches B, C, D and E over the 17 annual Mammoth Creek fish community surveys. Tick marks are the lower boundaries of 1-cm size intervals. For example, the length class labeled 12 cm contains fish with fork lengths greater or equal than 120 mm but less than 130 mm.

Table E-2. Estimated YOY brown trout abundance (i.e., $\hat{Y}_i$) and variance ((i.e., $V\hat{a}r(\hat{Y}_i)$) for each sample site for the annual 1988-2008 Mammoth Creek fish community surveys. Fish with fork lengths less than 120 mm were considered YOY.

YEAR	Estimate	BH	BL	CH	CL	DH	DL	EH	EL
1988	$\hat{Y}_i$	47	64	18	30	22	13	62	1
	$V\hat{a}r(\hat{Y}_i)$	858.49	38.16	0.95	2.93	0.50	0.25	2.92	0.00
1992	$\hat{Y}_i$	99	37	28	26	56	73	198	3
	$V\hat{a}r(\hat{Y}_i)$	6.48	2.33	2.79	1.20	4.88	0.44	3.51	0.07
1993	$\hat{Y}_i$	80	52	20	70	37	12	54	0
	$V\hat{a}r(\hat{Y}_i)$	124.21	5.85	3.61	64.59	0.63	0.53	5.99	0.00
1994	$\hat{Y}_i$	161	55	40	14	218	62	133	13
	$V\hat{a}r(\hat{Y}_i)$	54.05	2.91	113.91	0.00	17.90	8.07	846.00	0.11
1995	$\hat{Y}_i$	29	31	16	4	32	1	22	3
	$V\hat{a}r(\hat{Y}_i)$	13.94	6.58	12.70	0.07	12.56	0.00	286.05	0.00
1996	$\hat{Y}_i$	251	3	53	8	92	42	40	21
	$V\hat{a}r(\hat{Y}_i)$	1,158.79	0.13	9.39	1.12	28.05	1,019.65	24.08	0.50
1997	$\hat{Y}_i$	437	35	60	8	25	67	154	73
	$V\hat{a}r(\hat{Y}_i)$	112.93	3.65	3.10	0.26	8.98	2.26	4.34	3.97
1999	$\hat{Y}_i$	245	61	51	11	98	12	82	96
	$V\hat{a}r(\hat{Y}_i)$	551.40	111.75	5.50	0.25	96.81	0.28	5.24	26.69
2000	$\hat{Y}_i$	359	18	44	0	31	46	37	101
	$V\hat{a}r(\hat{Y}_i)$	535.64	11.56	0.13	0.00	2.75	1.22	3.19	31.30
2001	$\hat{Y}_i$	229	84	72	12	55	48	67	20
	$V\hat{a}r(\hat{Y}_i)$	237.59	11.04	4.13	0.28	2.58	20.96	29.54	0.35
2002	$\hat{Y}_i$	309	40	20	6	18	51	67	11
	$V\hat{a}r(\hat{Y}_i)$	324.50	6.45	1.10	0.02	11.56	10.16	8.68	1.61
2003	$\hat{Y}_i$	145	17	88	39	20	37	39	30
	$V\hat{a}r(\hat{Y}_i)$	99.76	0.15	183.14	2.47	0.54	11.36	3.33	0.05
2004	$\hat{Y}_i$	159	10	40	15	27	48	44	14
	$V\hat{a}r(\hat{Y}_i)$	170.09	0.74	0.88	0.08	3.60	2.58	5.84	1.51
2005	$\hat{Y}_i$	63	42	22	5	7	23	10	1
	$V\hat{a}r(\hat{Y}_i)$	127.08	1.20	0.92	0.00	0.02	3.37	0.03	0.54
2006	$\hat{Y}_i$	172	3	17	10	29	1	54	60
	$V\hat{a}r(\hat{Y}_i)$	163.35	0.07	3.99	7.31	53.22	0.00	9.04	8.61
2007	$\hat{Y}_i$	261	6	76	41	153	90	207	135
	$V\hat{a}r(\hat{Y}_i)$	321.74	0.44	7.28	168.74	11.30	106.65	49.32	2.50
2008	$\hat{Y}_i$	188	20	38	22	24	5	21	8
	$V\hat{a}r(\hat{Y}_i)$	29.25	0.11	3.50	3.68	0.39	0.20	0.32	0.08

Table E-3. Amounts of catchable-sized rainbow trout planted in Mammoth Creek during recent years. Data provided by CDFG (from Salamunovich 2009).

Year	Number	Pounds	Average Weight/Fish (pounds)
2004	12,426	7,367	0.89
2005	13,109	7,200	0.55
2006	14,583	7,250	0.54
2007	6,917	4,060	0.68
2008	9,326	5,330	0.57
Average	11,272	6,241	0.65

Finally, the ability to restrict inter-annual trend analysis and evaluation of potential relationships between annual population estimates and flow to YOY rainbow (and brown) trout was examined. Restricting these further analyses to YOY trout has two major advantages. First, using YOY rainbow trout could provide opportunities to evaluate trends in the "wild" population, because CDFG plants much larger-sized, catchable rainbow trout for the "put-and-take" recreational fishing in Mammoth Creek. Thus, YOY rainbow trout would be a more reliable indicator of "wild" populations. Second, restricting inter-annual analysis to YOY trout populations also reduces the confounding influence of angling pressure and harvest. Reliable creel census survey data are not available for Mammoth Creek. Angling pressure and success (harvest) can vary among locations along the creek, as well as vary temporally with weather, runoff and demographic patterns, which could affect population estimation of larger (than YOY) trout. In fact, Salamunovich (2006, 2007 and 2009) reported indirect evidence (discarded fishing tackle, parked vehicles) of relatively heavy angling pressure at certain sample sites, as well as direct evidence (persons actively angling near the sample sites) during the 2006 fish survey in Mammoth Creek.

However, during certain years of the 17-year study period, relatively few or no YOY wild rainbow trout were captured: at any sample sites in 1988; at sites BH, BL, EH and EL in 1992; at all sites but DH in 1993; at sites BL, CH, DH, EH and EL in 1995; at sties BL, CH and EL in 2001; and at sites CH, CL and EL in 2003. In addition, abundance estimation based upon those years with low sample site YOY catches result in unreliable and often unbounded population estimates, because the specific catch pattern of the multiple-pass depletion estimator (e.g., 1-0-0, 5-0-0; etc.) did not allow estimation of standard errors for individual sample-site population estimates. Population estimates of YOY wild rainbow trout among years, reaches and sample sites render problematic the quantitative evaluation (e.g., through least squares regression analysis) of temporal trends and potential relationships between YOY wild rainbow trout abundance and flow.

For the above reasons, annual rainbow trout ("wild" or hatchery) population estimates are of limited value in the assessment of inter-annual trends or potential relationships between abundance and flow in Mammoth Creek.

4.3.1 BROWN TROUT DATA UTILIZATION

For the analysis of brown trout abundance in Mammoth Creek, the annual fish community survey raw data was obtained from Mammoth Community Water District (MCWD) and utilized to estimate brown trout abundance (i.e., $\hat{Y}_i$) and variance (i.e., $V\hat{a}r(\hat{Y}_i)$) per sampled reach site (e.g., BH, BL, CH, CL, etc). The brown trout abundance and variance estimates were obtained through a multiple-pass depletion algorithm (Zippin 1956, 1958; White et al. 1982) executed by *Microfish 3.0 for Windows* software (Van Deventer and Platts 1986). The annual estimates per site thus obtained that are displayed in **Table E-4** were used to evaluate the annual brown trout abundances and variances over the entire creek.

Table E-4. Estimated brown trout abundance (i.e., $\hat{Y}_i$) and variance (i.e., $V\hat{a}r(\hat{Y}_i)$) for each sample site for the annual 1988-2008 Mammoth Creek fish community surveys.

YEAR	Estimate	BH	BL	CH	CL	DH	DL	EH	EL
1988	$\hat{Y}_i$	60	89	21	36	38	20	81	2
	$V\hat{a}r(\hat{Y}_i)$	18.09	9.85	0.72	2.45	1.20	0.35	4.25	0.31
1992	$\hat{Y}_i$	173	105	32	48	79	90	226	11
	$V\hat{a}r(\hat{Y}_i)$	5.74	1.81	2.59	2.94	6.77	0.59	4.68	0.15
1993	$\hat{Y}_i$	168	151	29	70	60	29	70	9
	$V\hat{a}r(\hat{Y}_i)$	132.37	10.31	7.56	64.59	0.90	1.25	4.36	0.07
1994	$\hat{Y}_i$	237	128	46	30	251	90	140	23
	$V\hat{a}r(\hat{Y}_i)$	54.42	2.57	23.06	1.18	18.54	10.20	177.74	0.04
1995	$\hat{Y}_i$	100	31	19	6	35	1	19	59
	$V\hat{a}r(\hat{Y}_i)$	17.00	3.84	10.23	0.10	11.53	0.00	11.13	0.44
1996	$\hat{Y}_i$	276	9	74	9	108	36	51	65
	$V\hat{a}r(\hat{Y}_i)$	686.65	0.01	7.13	0.90	21.05	19.39	20.12	0.23
1997	$\hat{Y}_i$	488	40	96	12	35	94	217	102
	$V\hat{a}r(\hat{Y}_i)$	125.64	5.69	7.31	0.28	18.84	4.05	6.90	5.77
1999	$\hat{Y}_i$	303	76	97	17	125	35	124	125
	$V\hat{a}r(\hat{Y}_i)$	246.05	48.55	18.10	0.66	27.45	3.04	4.39	18.27
2000	$\hat{Y}_i$	379	36	60	5	46	66	67	128
	$V\hat{a}r(\hat{Y}_i)$	370.95	2.45	0.27	0.03	1.22	1.84	11.22	27.01
2001	$\hat{Y}_i$	268	97	85	14	65	66	83	30
	$V\hat{a}r(\hat{Y}_i)$	151.59	9.31	4.54	0.40	2.67	11.57	19.72	0.26
2002	$\hat{Y}_i$	331	51	60	14	32	95	106	15
	$V\hat{a}r(\hat{Y}_i)$	234.24	9.33	2.20	0.03	7.04	4.92	7.20	0.91
2003	$\hat{Y}_i$	163	26	108	53	35	81	79	35
	$V\hat{a}r(\hat{Y}_i)$	97.04	0.07	58.16	2.44	3.04	4.25	1.86	0.04
2004	$\hat{Y}_i$	181	25	74	48	50	88	77	33
	$V\hat{a}r(\hat{Y}_i)$	62.92	0.14	1.88	5.02	2.72	2.28	4.74	3.40
2005	$\hat{Y}_i$	75	45	36	11	22	49	38	32
	$V\hat{a}r(\hat{Y}_i)$	84.86	1.06	2.88	0.01	0.46	5.95	0.65	1.05
2006	$\hat{Y}_i$	186	17	27	17	70	16	69	81
	$V\hat{a}r(\hat{Y}_i)$	109.39	0.15	2.99	3.99	10.98	0.31	5.31	6.90
2007	$\hat{Y}_i$	284	13	98	44	194	99	233	173
	$V\hat{a}r(\hat{Y}_i)$	169.68	0.25	4.33	54.51	9.27	32.68	41.10	2.20
2008	$\hat{Y}_i$	207	32	62	29	55	14	89	59
	$V\hat{a}r(\hat{Y}_i)$	27.84	0.23	2.06	0.98	0.24	0.10	2.68	0.35

4.4 ANALYTICAL PROCEDURE

4.4.1 BROWN TROUT ABUNDANCE

The annual abundance of brown trout over the entire sample area (i.e., reaches B + C + D + E) was estimated using the formula for a two-stage design with equal-sized primary units[2] (Hankin 1984; 1986; Cochran 1977; Raj 1968):

$$\hat{Y}_{\mathrm{T}} = \frac{N}{n} \times \sum_{i=1}^{n} \hat{Y}_i \,, \tag{1}$$

where $\hat{Y}_{\mathrm{T}}$ is the estimated abundance of brown trout over the entire study area in a particular surveyed year, and $\hat{Y}_i$ is the brown trout abundance in sampled site i for the corresponding survey year, obtained through the multiple-pass Zippin's depletion algorithm and displayed in Table E-4. N is the total number of potential sampling sites for the particular year (e.g., N = 473 in 1988 and N = 158 from 1992-2008, Table E-1), and n is the total number of sampling sites electrofished that particular year (e.g., n = 8 in 1988 and 1992-2008).

The estimated variance for the annual abundance estimates (Hankin 1984, 1986; Cochran 1977; Raj 1968) was calculated as:

$$\hat{V}\left(\hat{Y}_{\mathrm{T}}\right) = \frac{N \times \left(N - n\right) \times \sum_{i=1}^{n} \left(\hat{Y}_i - \overline{Y}\right)^2}{n \times \left(n - 1\right)} + \frac{N}{n} \times \sum_{i=1}^{n} V\hat{a}r(\hat{Y}_i) \,, \tag{2}$$

where $\overline{Y} = \sum_{i=1}^{n} \hat{Y}_i \Big/ n$, and $V\hat{a}r(\hat{Y}_i)$ are the site-specific variances from Table E-4.

For illustrative purposes only, approximate 95% confidence intervals were calculated for the annual abundance of brown trout using the formula suggested in Skalski and Robson (1992) to correct for normality and provide confidence intervals. This formula expresses the 95% confidence interval as:

$$P\left(\hat{Y}_{\mathrm{T}} \times e^{-Z_{1-0.05/2} \times \sqrt{\hat{V}(\hat{Y}_{\mathrm{T}}) / \hat{Y}_T^2}} \leq Y_{\mathrm{T}} \leq \hat{Y}_{\mathrm{T}} \times e^{-Z_{0.05/2} \times \sqrt{\hat{V}(\hat{Y}_{\mathrm{T}}) / \hat{Y}_T^2}} \right) = 1 - 0.05 \,, \tag{3}$$

where $Z_{1-0.05/2}$ and $Z_{0.05/2}$ are the inverse of the standard normal cumulative distribution with probabilities 0.975 and 0.025, respectively.

4.4.1.1 YOY BROWN TROUT ABUNDANCE

The annual abundance of YOY brown trout over the entire sample area and its corresponding variance and approximate 95% confidence intervals were calculated by applying equations (1),

[2] In this design the primary sampling units are the H and L sites that in theory have an equal size of 300 ft since 1992. The first stage refers to the selection of these H and L sites, 2 per year and reach. The second stage refers to the three passes conducted in each site.

(2) and (3) to the *Microfish* estimates of abundance and variance per sampled site and year (Table E-2).

4.4.2 YOY BROWN TROUT DENSITY

Because the formula for the estimation of annual abundances (equation 1) is based on an expansion of the sum of sample site abundances, obtained from the multiple-pass Zippin's depletion algorithm, to the number of potential sampling sites, and this in turn depends on the reach lengths, annual average YOY brown trout densities also were calculated.

First, $D_{R,j}$, the YOY brown trout densities at each of the sampled sites, were calculated by dividing the estimated abundances from Table E-2 by the length of the sample site displayed in Table E-1.

Second, for subsequent trend analyses, three annual averages of YOY brown trout densities were calculated.

(1) ***Average density for the entire creek (*** $\bar{D}_{\mathrm{T}}$ ***)***

$\bar{D}_{\mathrm{T}}$ was calculated as $\bar{D}_{\mathrm{T}} = \sum_{R=1}^{4}\sum_{j=1}^{2} D_{R,j} / n$, where $D_{R,j}$ is the YOY brown trout density in reach *R* and sampling site *j*, and *n* is the total number of sample sites electrofished during the year (e.g., *n* = 8 in 1988 and 1992-2008).

(2) ***Average density at a particular reach (*** $\bar{D}_R$ ***)***

$\bar{D}_R$ was calculated as $\bar{D}_R = \sum_{j=1}^{2} D_{R,j} / n_R$, where n_R is the number of sample sites electrofished at reach *R* during the year (two sites sampled within each reach, annually).

(3) ***Average three-reach density (*** $\bar{D}_R^{'}$ ***)***

$\bar{D}_R^{'}$ was calculated as $\hat{D}_{\mathrm{T}}^{'} = \sum_{R \neq W}^{3}\sum_{j=1}^{2} D_{R,j} / (n - n_W)$, where *W* indicates the reach excluded from the calculation. The three-reach annual average densities were used to appraise the relative importance of a particular reach in the average annual density for the entire creek (see Temporal Trend Analyses, below).

4.4.2.1 TEMPORAL TREND ANALYSES

Minimum least squares was utilized to estimate the slope (β) and intercept (α) of simple linear models (i.e., $Y = \alpha + \beta \times X$) relating the response variable *Y* (e.g., annual abundance or average densities) to a temporal variable *X* whose values were obtained by subtracting 1987 from the survey year (e.g., the *X* value for year 1992 was *x* = 1992 - 1987 = 5). From these linear models a decline in Mammoth Creek brown trout population can be inferred whenever the fit of the models to the abundance or density data provide statistically significant negative slopes (i.e., $\hat{\beta} < 0$).

Temporal trend analyses were conducted for the overall (all age classes) annual brown trout population estimates (number of fish), as well as separately for annual YOY brown trout population estimates for the entire creek (i.e., Sherwin St. crossing to the confluence with Hot Creek). In addition, temporal trend analysis was conducted for average annual YOY brown trout density (fish/mile) estimates for the entire creek, and on a reach-by-reach basis for the 17-year period of record.

Additional temporal trend analyses of annual YOY brown trout densities emphasized recent years (1999 through 2008) because: (1) the recent period represents an uninterrupted sequence of annual fish population sampling; (2) the period 1999-2008 is characterized by a generally "wetter" hydrology than the period extending from 1988-1997; and (3) MCWD has been operating in accordance with the proposed bypass flow requirements (with the exception of a 4 cfs mean daily bypass flow requirement at OLD395) since the Mono County Superior Court issued its ruling in 1996. Thus, temporal trend analyses were conducted for average annual YOY brown trout densities (fish/mile) for the entire creek, and on a reach-by-reach basis for recent years (1999-2008).

Also for recent years (1999-2008), temporal trend analyses were conducted to examine the potential influence of specific reaches (i.e., B, C, D or E) to overall temporal trends by removing the average annual YOY brown trout density for a specific reach, recalculating average annual densities for the entire creek for the remaining three reaches, and repeating the regression analysis to obtain temporal trends. Then, regression statistics (i.e., r^2 and P values) and resultant slopes of the fitted regressions were compared between the "with" and "without" specific reach scenarios. This process was conducted for each of the specific reaches (i.e., B, C, D or E).

4.4.3 Potential Relationships Between YOY Brown Trout Density and Flow

Mammoth Creek daily mean flows measured at the Old Mammoth Road (OMR) gage during the years 1987 through 2008 were utilized to calculate two flow metrics that were used, in turn, as explanatory, or independent, variables in simple linear regression analyses performed on the annual averages of YOY brown trout densities for the entire creek (i.e., $\bar{D}_T$) to examine potential relationships between YOY brown trout densities and flows.

The first flow variable, hereinafter referred to as OMR Low Flow Quartile, was used to represent the low summer flows, and was defined as the average of all daily flows lower than the 25th percentile of the cumulative distribution of all daily flows at the Old Mammoth Road gage from the day of the annual spring/summer maximum daily flow through the day before the start of the annual electrofishing survey.

The second flow variable, hereinafter referred to as OMR High Flow, was calculated as the highest 7-day running average of the mean daily flows during a particular year, which serves as an index of the annual spring/early summer peak runoff.

For both OMR Low Flow Quartile and OMR High Flow, linear regression analyses were conducted using the flow variables as independent (explanatory) variables and average annual YOY brown trout densities for the entire creek as the dependent variable for the 17-year period of record.

Table E-5 displays the values of OMR Low Flow Quartile and OMR High Flow, as well as the dates involved in the calculations.

Table E-5. Flow variables used in regressions with annual averages of YOY brown trout densities. Flows were measured at the Old Mammoth Road (OMR) gage. OMR high flow was calculated as the highest 7-day running average of the daily mean flows of each particular year. OMR low flow quartile was defined as the average of all daily flows lower than the 25th percentile of all daily flows, from the day of the annual spring/summer maximum through the day before the start of the annual electrofishing survey. Light yellow cells mark years with annual electrofishing surveys.

YEAR	OMR Low Flow Quartile			OMR High Flow	
	Daily Maximum Date	Eve of Survey Start Date	Flow (cfs)	7-Day-MA Maximum Date	Flow (cfs)
1987	05/15	*N/A*	*N/A*	05/12	59.6
1988	05/23	11/01	4.5	05/23	50.2
1989	05/10	*N/A*	*N/A*	05/09	46.2
1990	06/11	*N/A*	*N/A*	06/07	34.1
1991	06/14	*N/A*	*N/A*	06/09	84.6
1992	05/12	10/20	5.0	05/12	40.6
1993	06/29	10/11	8.1	06/15	120.2
1994	06/01	10/03	5.9	05/31	61.8
1995	07/11	10/31	11.8	07/06	214.8
1996	05/17	10/02	10.0	05/15	158.7
1997	06/02	10/03	10.0	05/30	109.2
1998	07/11	*N/A*	*N/A*	07/01	172.3
1999	06/17	09/23	8.9	06/16	112.4
2000	05/29	10/09	6.6	05/24	109.9
2001	05/18	10/08	5.8	05/22	85.2
2002	06/02	09/29	6.1	05/31	78.0
2003	05/30	09/28	6.3	05/29	129.7
2004	05/29	10/03	6.1	05/29	56.6
2005	06/15	09/28	8.5	06/11	148.1
2006	06/07	10/10	8.7	06/05	196.2
2007	05/19	10/09	5.0	05/17	36.7
2008	05/20	10/07	5.9	05/17	71.0

As an example, **Figure E-4** illustrates the OMR daily flows during 2003 and their relationship to the values of OMR Low Flow Quartile and OMR High Flow during that year.

Potential relationships between YOY brown trout densities and flows during the low flow period were further examined using an alternate expression of low flows, hereinafter referred to as OMR Low Flow. First, the average flow at OMR was calculated for each of the low flow months (August, September, and October) over the 17 years included in the analysis. Second, the month with the lowest average flow (among August, September, and October) for each of the 17 years was identified. Third, linear regression analysis was conducted using the identified low flow variable as the independent (explanatory) variable, and average annual YOY brown trout densities for the entire creek as the dependent variable for the 17 years included in the analysis.

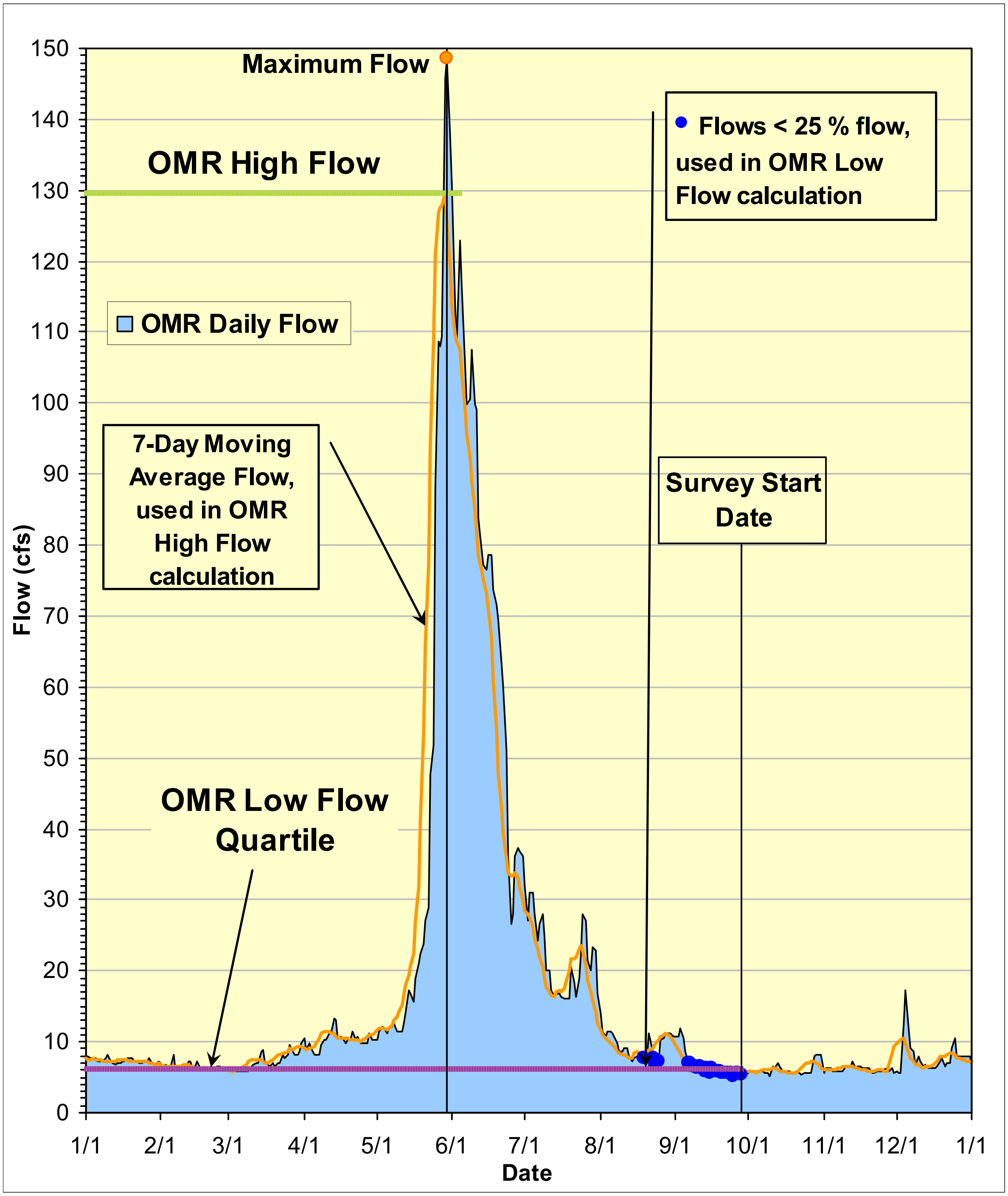

Figure E-4. Daily OMR flows in 2003 and their relationship to the values of OMR low flow quartile and OMR high flow used in the study of potential relationships between YOY brown trout densities and flows.

It was suggested by the Mammoth Creek Technical Team, comprised of various stakeholders including CDFG, USGS, LADWP, non-governmental organizations (NGOs) and others, in August 2006 that streambed cleansing (via scouring flows) may result in additional substrate interstitial space availability for the colonization of benthic macroinvertebrates. It was further suggested that these potentially "improved" habitat conditions (i.e., increased macroinvertebrate production as a food supply) for YOY trout rearing may not be evident in YOY trout densities within a year due to the potential flushing (or displacement) of YOY trout from their habitats, but may be reflected by YOY trout densities in the subsequent year. To examine this potential phenomenon, OMR High Flow variables were lagged backward by one year, then regressed against the annual average YOY brown trout densities for the entire creek for the 17-year period of record. For example, OMR High Flow during 1992 was regressed against average YOY brown trout density during 1993, OMR High Flow during 1993 regressed against average YOY brown trout density during 1994, and so forth.

5.0 RESULTS

5.1 NATIVE FISH ABUNDANCE

During the 17 years of Mammoth Creek fishery survey records, catches of the two native fish species Owens sucker (*Catostomus fumeiventris*) and tui chub (*Gila bicolor*) were almost entirely restricted to Reach E, particularly to the lowermost site EL (**Table E-6**). Over the 17 years of electrofishing surveys, 99.8% of the Owens sucker and 100% of the Owens tui chub were caught in Reach E. Only in the 1999 Mammoth Creek fishery survey were two Owens suckers caught outside of Reach E, at the next lowermost site (DH).

Table E-6. Numbers of Owens sucker and tui chub caught per sampling site during the 17 annual electrofishing surveys conducted in Mammoth Creek.

Site / Year	Owens sucker (Numbers of fish caught)								Tui chub (Numbers of fish caught)							
	BH	BL	CH	CL	DH	DL	EH	EL	BH	BL	CH	CL	DH	DL	EH	EL
1988	0	0	0	0	0	0	0	37	0	0	0	0	0	0	0	19
1992	0	0	0	0	2	0	0	205	0	0	0	0	0	0	0	417
1993	0	0	0	0	0	0	0	425	0	0	0	0	0	0	0	855
1994	0	0	0	0	0	0	0	524	0	0	0	0	0	0	0	392
1995	0	0	0	0	0	0	1	57	0	0	0	0	0	0	0	69
1996	0	0	0	0	0	0	0	84	0	0	0	0	0	0	0	48
1997	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	1
1999	0	0	0	0	2	0	0	49	0	0	0	0	0	0	0	6
2000	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	2
2001	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	2
2002	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
2003	0	0	0	0	0	0	0	54	0	0	0	0	0	0	13	6
2004	0	0	0	0	0	0	0	122	0	0	0	0	0	0	0	30
2005	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	2
2006	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	6
2007	0	0	0	0	0	0	0	42	0	0	0	0	0	0	0	1
2008	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	5

Because only the total catches per site of Owens sucker and tui chub were reported for the 17 years of Mammoth Creek fishery surveys, but records of the site-specific catch removal patterns of the two species were not kept or reported during the 1988, 1992-1994, 2000 and 2005 fishery surveys, the estimation of site-specific population abundances of the species using *Microfish 3.0 for Windows* was not possible during those years, and consequently the estimation of annual abundance estimates of the species over the entire sample area (i.e., reaches B + C + D + E) using the formula for a two-stage design with equal-sized primary units (Equation 1) was precluded.

Because of the above-mentioned reasons, analyses of the annual abundances of Owens sucker and tui chub in Mammoth Creek were represented by the annual averages of the standardized abundances of the species at sites EL and EH, where standardized abundances are the numbers of the species annually caught at sites EL or EH divided by the length in miles of the particular sampling site (**Table E-7**).

Table E-7. Standardized abundances of Owens sucker and tui chub for the 17 annual electrofishing surveys conducted in Mammoth Creek Reach E.

Site / Year	Owens Sucker Standardized Abundance (Fish / mile)			Tui Chub Standardized Abundance (Fish / mile)		
	EH	EL	Reach E Average	EH	EL	Reach E Average
1988	0	1,954	977	0	1,003	502
1992	0	3,608	1,804	0	7,339	3,670
1993	0	7,480	3,740	0	15,048	7,524
1994	0	9,222	4,611	0	6,899	3,450
1995	18	1,003	510	0	1,214	607
1996	0	1,478	739	0	845	422
1997	0	35	18	18	18	18
1999	0	862	431	0	106	53
2000	18	317	167	0	35	18
2001	0	106	53	0	35	18
2002	0	35	18	0	35	18
2003	0	950	475	229	106	167
2004	0	2,147	1,074	0	528	264
2005	0	317	158	0	35	18
2006	0	192	96	0	105	52
2007	0	704	352	0	17	8
2008	0	189	94	0	86	43

To infer potential relationships between the abundances of Owens sucker and tui chub and Mammoth Creek flows, the series of annual standardized abundances were visually inspected in conjunction with the series of annual High Flow (i.e., the annual highest 7-day running average of the mean daily flows at the OMR Gage) and Low Flow (i.e., the lowest among the annual average flows at OMR Gage for the months August, September and October), measured at the MCWD gage at Old Mammoth Road (OMR) and at the LADWP gage at Hwy 395 (OLD395). Annual High and Low Flows for the OMR and OLD395 gages are displayed in **Table E-8**. Linear least squares estimation was used to evaluate what percent of the abundance inter-annual variability was explained by the flow variables.

Table E-8. OMR and OLD395 flow variables used in regressions with annual averages of Owens sucker and tui chub standardized abundances in Reach E. OLD395 and OMR High Flows were calculated as the highest seven-day running average of the daily mean flows of each particular year. OLD395 and OMR Low Flows corresponded to the lowest among the annual average flows for the months August, September and October. Light yellow cells mark years with annual electrofishing surveys.

YEAR	OLD395 Low Flow		OMR Low Flow		OLD395 High Flow		OMR High Flow	
	Month with Minimum Monthly Flow	Monthly Average Flow (cfs)	Month with Minimum Monthly Flow	Monthly Average Flow (cfs)	7-Day-MA Maximum Date	Flow (cfs)	7-Day-MA Maximum Date	Flow (cfs)
1988	October	3.1	October	4.7	05/24	30.6	05/23	50.2
1989	September	5.5	October	6.3	05/19	59.5	05/09	46.2
1990	October	2.5	October	3.9	06/07	23.3	06/07	34.1
1991	October	5.2	October	6.2	06/09	80.1	06/09	84.6
1992	October	3.8	October	5.4	05/12	36.3	05/12	40.6
1993	October	8.9	October	8.0	06/24	119.3	06/15	120.2
1994	September	4.8	September	6.2	05/31	49.9	05/31	61.8
1995	October	21.2	October	12.1	07/06	245.7	07/06	214.8
1996	October	10.9	October	8.3	05/15	179.4	05/15	158.7
1997	October	10.7	October	7.2	05/30	121.0	05/30	109.2
1998	October	17.0	October	11.2	06/30	185.1	07/01	172.3
1999	October	8.2	October	7.5	06/16	113.6	06/16	112.4
2000	September	8.5	September	7.1	05/24	104.0	05/24	109.9
2001	October	5.5	September	6.0	05/22	85.5	05/22	85.2
2002	October	5.9	September	6.2	06/01	72.4	05/31	78.0
2003	October	6.7	October	5.9	05/30	126.1	05/29	129.7
2004	September	5.7	September	6.5	06/03	57.1	05/29	56.6
2005	October	11.1	October	7.9	05/28	153.6	06/11	148.1
2006	October	11.0	September	10.4	06/05	218.4	06/05	196.2
2007	September	4.4	September	5.2	05/18	34.1	05/17	36.7
2008	September	5.5	September	5.8	05/18	59.5	05/17	71.0

5.1.1 POTENTIAL RELATIONSHIPS OF OWENS SUCKER AND TUI CHUB WITH TROUT ABUNDANCES

The series of 17 annual standardized abundances of Owens sucker and tui chub indicate that the highest abundances of both species occurred in the years 1992 through 1994 when trout abundances in Reach E were relatively moderate to low (**Figure E-5**). Conversely, low to very low Owens sucker and tui chub abundances occurred in the years 1997, 1999, 2000 and 2007 when the Reach E abundances of brown and/or rainbow trout were at their highest.

The multiple linear regression analysis of Owens sucker standardized abundance (i.e., Y_{OS}) as a function of the standardized abundances for tui chub, brown trout and "wild" rainbow trout (i.e., Y_{TC}, Y_{BT} and Y_{WRT}, respectively) showed a strong and highly significant multiple correlation coefficient (*R* = 0.865; *P* = 0.0003). The resulting multiple regression equation was:

$$\hat{Y}_{OS} = 500.741 + 0.529 \times Y_{TC} + 0.027 \times Y_{BT} - 0.565 \times Y_{WRT}, \qquad \textbf{(1)}$$

where 0.529, 0.027 and -0.565 are the three estimated partial regression coefficients.

This equation indicates that the standardized abundance of Owens sucker would increase by 0.529 for a unit increase in tui chub abundance if the abundances of both trout species were held constant. Similarly, the standardized abundance of Owens sucker would increase only by 0.027 for a unit increase in brown trout abundance if the abundances of rainbow trout and tui chub were held constant. Moreover, the standardized abundance of Owens sucker would decrease by 0.565 for a unit increase in rainbow trout abundance if the abundances of brown trout and Owens tui chub were held constant. However, of the three partial regression coefficients, only the coefficient for Y_{TC} could be considered statistically different from zero (P = 0.0001). The partial regression coefficients for Y_{BT} and Y_{WRT} could not be considered statistically different from zero (P = 0.909 and P = 0.404, respectively).

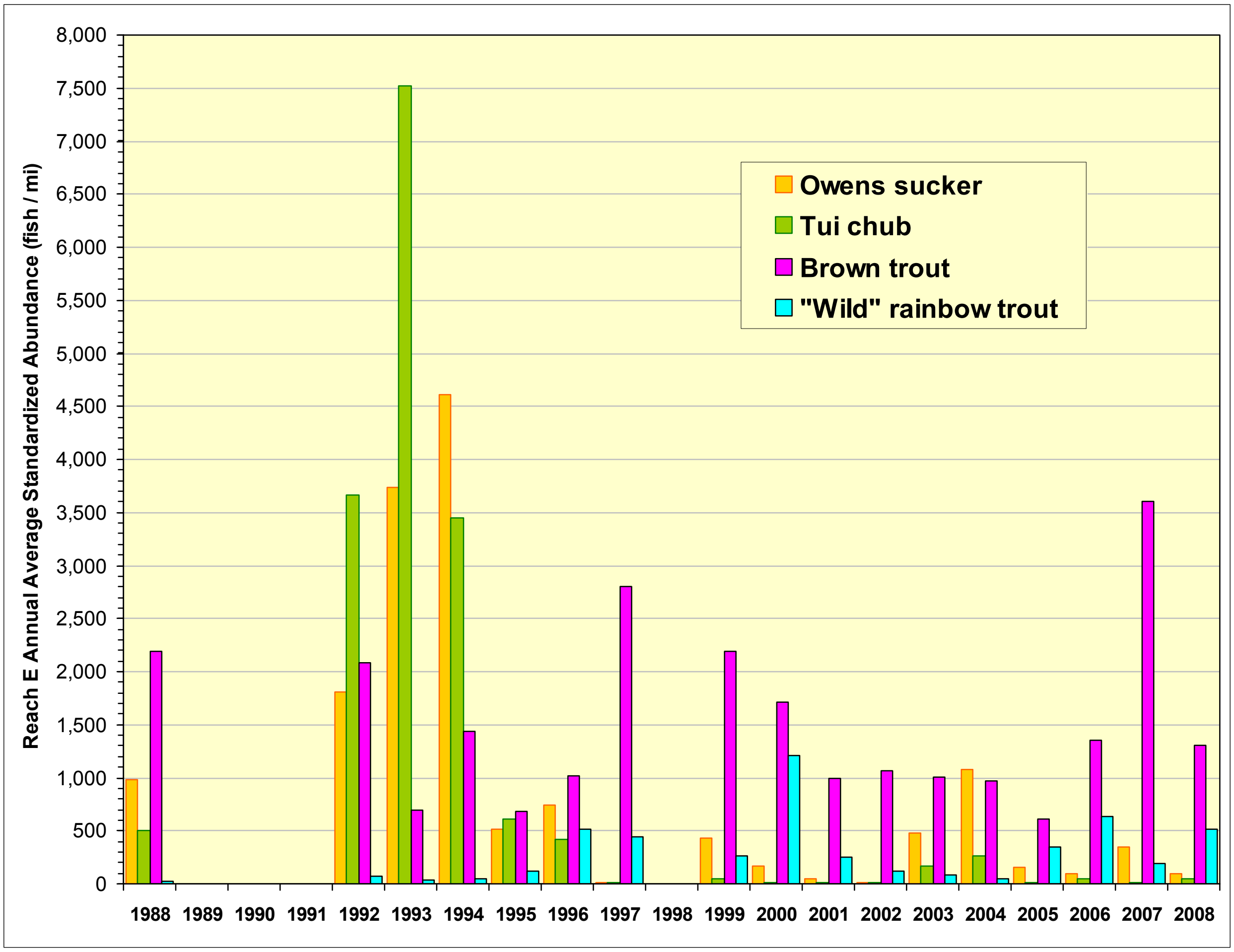

Figure E-5. Annual standardized abundance estimates (fish/mile) of Owens sucker, Owens tui chub, brown trout and "wild" rainbow trout in Reach E of Mammoth Creek, 1988-2008.

The multiple linear regression analysis of Owens tui chub standardized abundance (i.e., Y_{TC}) as a function of the standardized abundances for Owens sucker, brown trout and "wild" rainbow trout showed a high and highly significant multiple correlation coefficient (R = 0.86; P = 0.0005). The resulting multiple regression equation was:

$$\hat{Y}_{TC} = 74.109 + 1.293 \times Y_{OS} - 0.156 \times Y_{BT} - 0.041 \times Y_{WRT}\,. \qquad \textbf{(2)}$$

The partial regression coefficients for Y_{TC} of equation (2) suggest that the standardized abundance of Owens tui chub would increase by 1.293 for a unit increase in Owens sucker abundance if the abundances of both trout species were held constant, but it would decrease by 0.156 for a unit increase in brown trout abundance, and by 0.041 for a unit increase in "wild" rainbow trout abundance. Although decreases in the abundance of Owens tui chub with increases in trout abundances were expected given that Owens tui chub are potential prey for trout, the degree of change expressed in the partial regression coefficients for Y_{BT} and Y_{WRT} could not be considered statistically different from zero (P = 0.668 and P = 0.970, respectively).

5.1.2 POTENTIAL RELATIONSHIPS OF OWENS SUCKER AND TUI CHUB WITH OMR FLOW

The comparison of the 17 annual standardized abundances of Owens sucker and tui chub with the annual values of OMR High Flow and OMR Low Flow suggests that the highest abundances of the years 1992 through 1994 occurred during a period when the values of both annual expressions of OMR flows were at relatively low to intermediate values (**Figure E-6**). However, in 1995 and 2006 OMR flows (both High and Low) were the first and second highest over the 17-year period, and Owens sucker and tui chub abundances were relatively low.

The annual standardized abundances of Owens sucker and tui chub in Reach E during the period 1988 through 2008 were regressed against the lowest average monthly OMR flows (among August, September, and October) for each year to assess potential relationships between the annual abundances and the low Mammoth Creek flows of late summer and autumn, which precede the surveys each year. The results of the regression analysis for both Owens sucker (**Figure E-7**) and tui chub (**Figure E-8**) suggested decreasing abundances with increasing OMR Low Flow. However, the slopes of the regression lines cannot be considered significantly different from zero (P = 0.703 for the Owens sucker regression and P = 0.996 for the Owens tui chub regression), and both fitted lines explained less than one percent of the abundance variability (r^2 = 0.010 and r^2 = 0.000002 for Owens sucker and tui chub, respectively).

The annual standardized abundances of Owens sucker and tui chub were also regressed against OMR High Flow to assess potential relationships between the annual densities and the peak Mammoth Creek flows of late spring/early summer. Similar to what was observed with previous regressions, the results of the analysis for both Owens sucker (**Figure E-9**) and tui chub (**Figure E-10**) suggested decreasing abundances with increasing OMR High Flow, but both fitted lines explained only a very small percentage of the abundance variability (r^2 = 0.054 and r^2 = 0.015 for Owens sucker and tui chub, respectively), and both slopes cannot be considered significantly different from zero (P = 0.368 and P = 0.641, for the Owens sucker and tui chub regressions, respectively).

5.1.3 POTENTIAL RELATIONSHIPS OF OWENS SUCKER AND TUI CHUB WITH OLD395 FLOW

Similar to what was observed with OMR flows, the comparison of the 17 annual standardized abundances of Owens sucker and tui chub with the annual values of OLD395 High Flow and OLD395 Low Flow suggests that the highest abundances of the years 1992 through 1994 occurred during a period when the values of both annual expressions of OLD395 flows were at relatively low to intermediate values (**Figure E-11**). However, in 1995 and 2006 OLD395 flows (both High and Low) were the first and second highest over the 17-year period, and Owens sucker and tui chub abundances were relatively low.

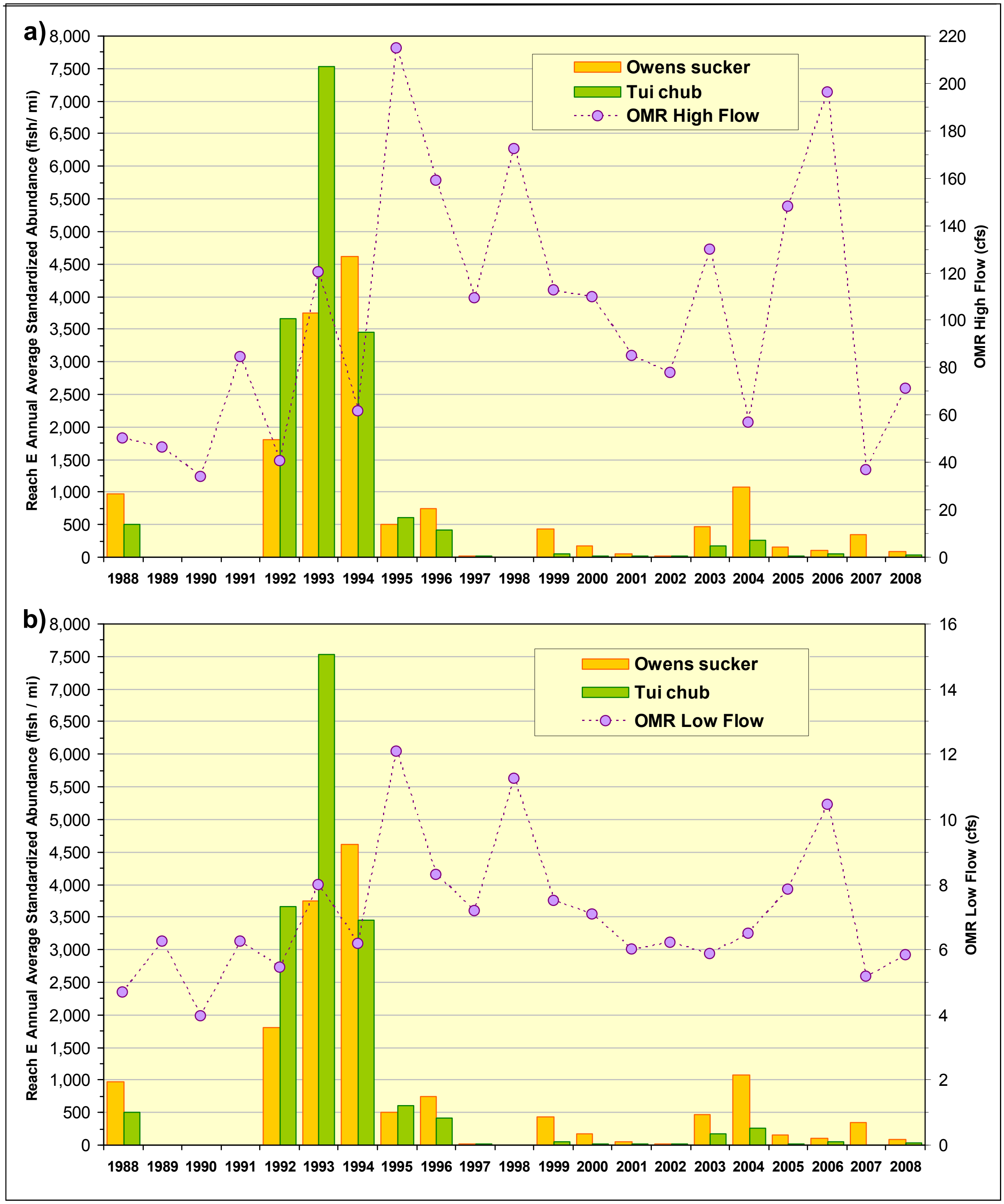

Figure E-6. Annual standardized abundance estimates (fish/mile) of Owens sucker and tui chub, at Reach E of Mammoth Creek and two annual expressions of OMR flows during 1988-2008: (a) OMR High Flow and (b) OMR Low Flow.

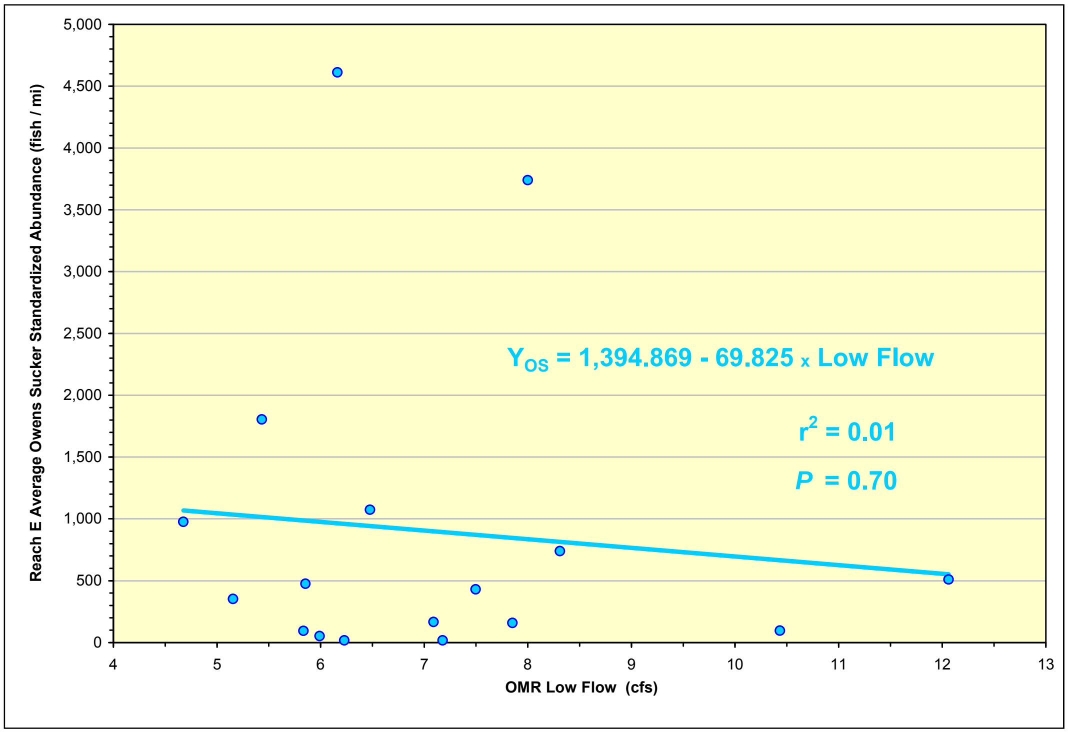

Figure E-7. Annual standardized abundance of Owens sucker (fish/mile) as a function of OMR Low Flow (cfs) and corresponding fitted linear regression line for the period 1988 through 2008.

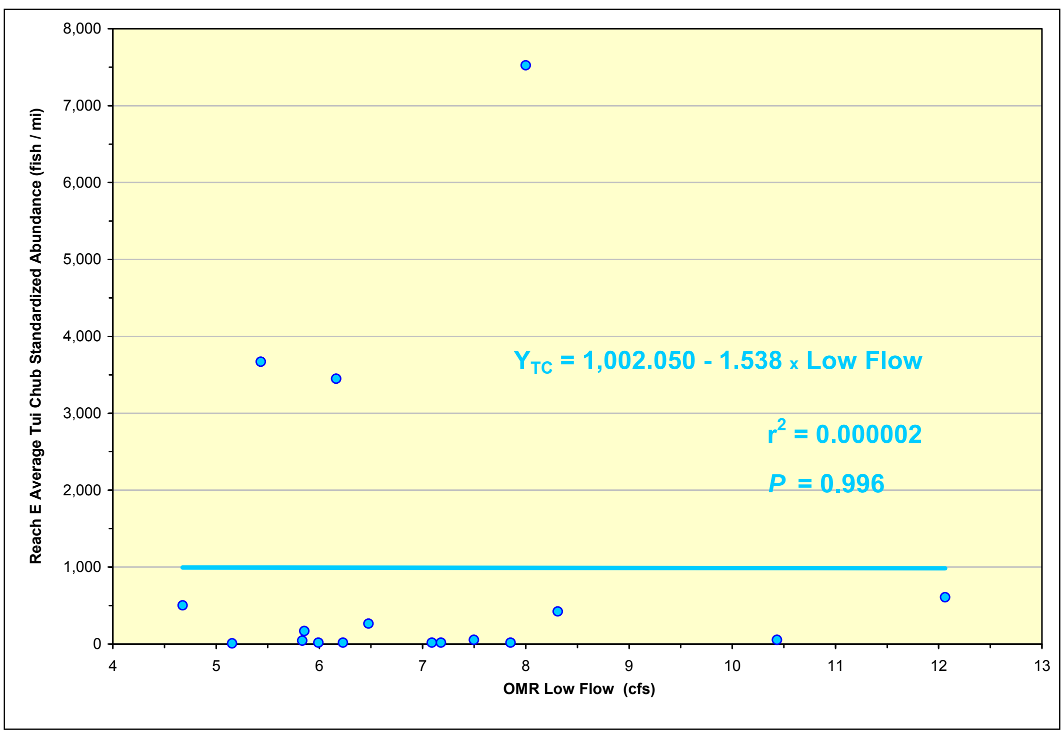

Figure E-8. Annual standardized abundance of Owens tui chub (fish/mile) as a function of OMR Low Flow (cfs) and corresponding fitted linear regression line for the period 1988 through 2008.

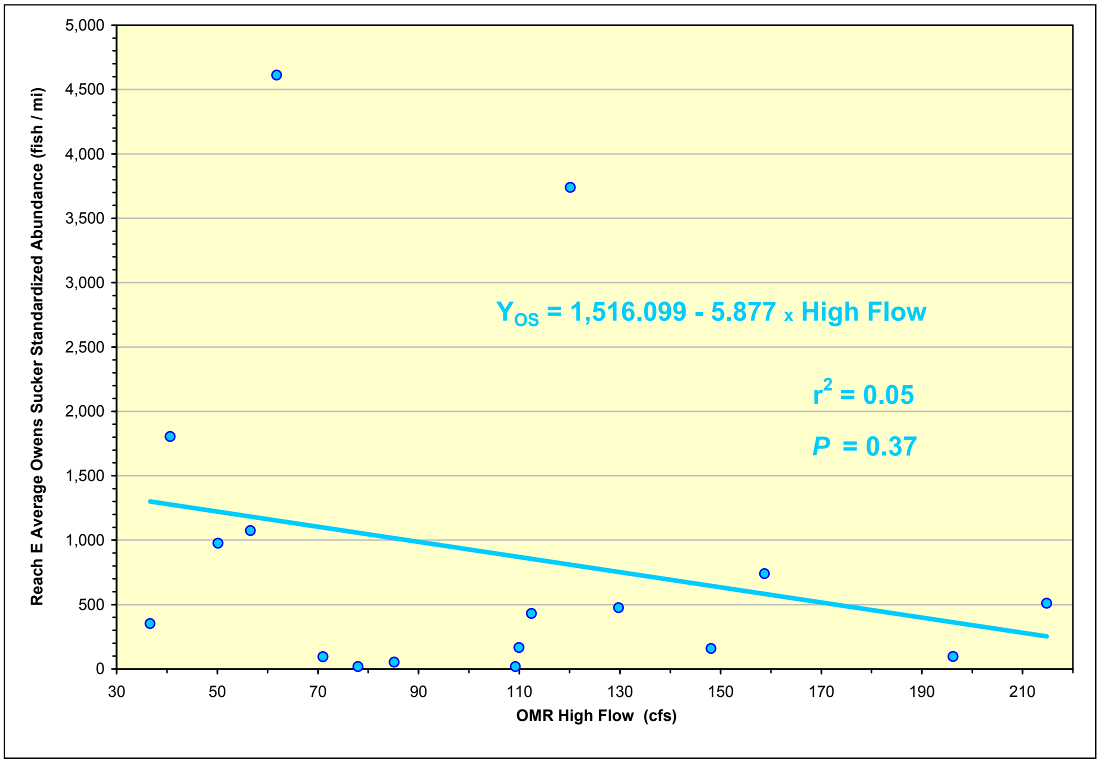

Figure E-9. Annual standardized abundance of Owens sucker (fish/mile) as a function of OMR High Flow (cfs) and corresponding fitted linear regression line for the period 1988 through 2008.

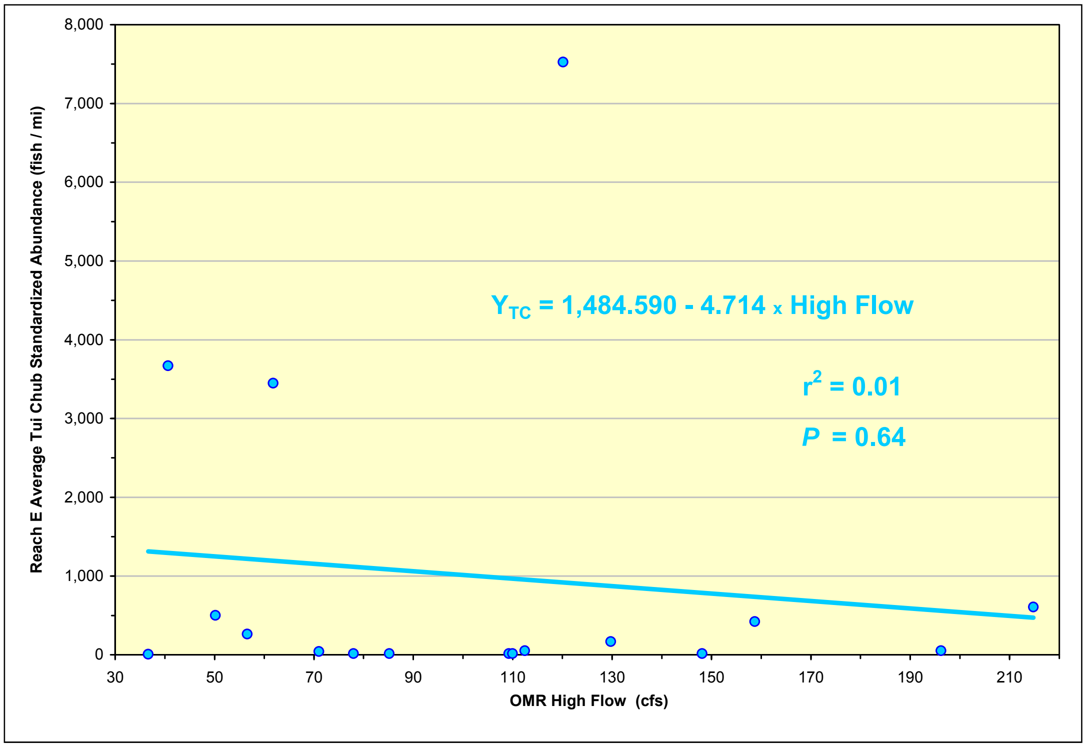

Figure E-10. Annual standardized abundance of Owens tui chub (fish/mile) as a function of OMR High Flow (cfs) and corresponding fitted linear regression line for the period 1988 through 2008.

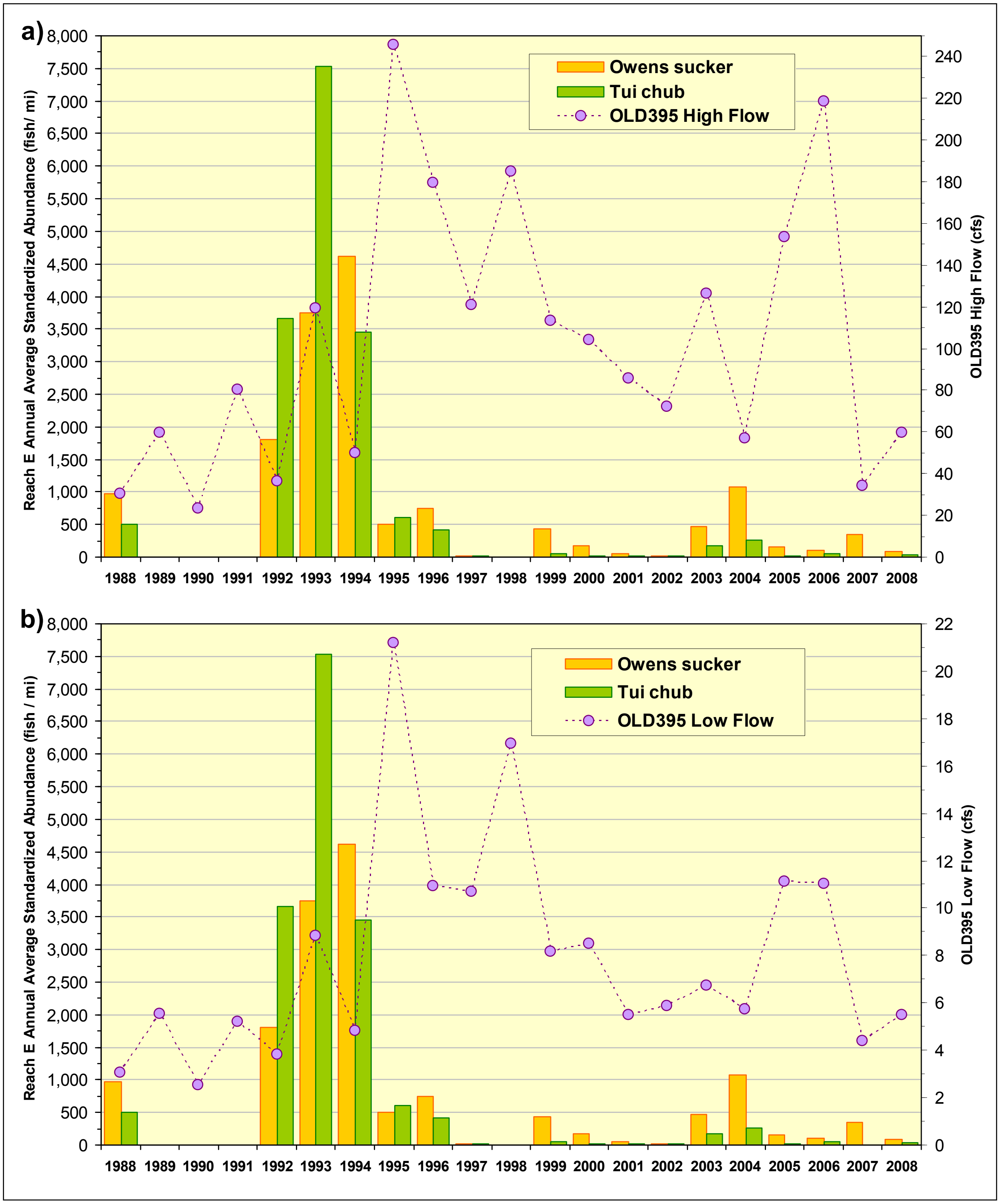

Figure E-11. Annual standardized abundance estimates (fish/mile) of Owens sucker and tui chub, in Reach E of Mammoth Creek and two annual expressions of OLD395 flows during 1988-2008: (a) OLD395 High Flow and (b) OLD395 Low Flow.

The annual standardized abundances of Owens sucker and tui chub in Mammoth Creek Reach E during the period 1988 through 2008 were regressed against the lowest average monthly OLD395 flows (among August, September, and October) for each year to assess potential relationships between the annual abundances and the low Mammoth Creek flows of late summer and autumn, which precede the surveys each year. The results of the regression analysis for both Owens sucker (**Figure E-12**) and tui chub (**Figure E-13**) suggested decreasing abundances with increasing OLD395 Low Flow. Similar to what was shown by the regressions with OMR Low Flow, the slopes of the regression lines cannot be considered significantly different from zero (P = 0.438 for the Owens sucker regression and P = 0.710 for the Owens tui chub regression), and both fitted lines explained less than four percent of the abundance variability (r^2 = 0.041 and r^2 = 0.009 for Owens sucker and tui chub, respectively).

The annual standardized abundances of Owens sucker and tui chub were also regressed against OLD395 High Flow to assess potential relationships between the annual densities and the peak Mammoth Creek flows of late spring/early summer. Similar to what was observed with previous regressions, the results of the analysis for both Owens sucker (**Figure E-14**) and tui chub (**Figure E-15**) suggested decreasing abundances with increasing OLD395 High Flow, but both fitted lines explained only a very small percentage of the abundance variability (r^2 = 0.062 and r^2 = 0.015 for Owens sucker and tui chub, respectively), and both slopes cannot be considered significantly different from zero (P = 0.334 and P = 0.605, for the Owens sucker and tui chub regressions, respectively).

5.1.4 NATIVE FISH ABUNDANCE DISCUSSION

Salamunovich (2009) suggested that the relatively high numbers of native fish captured in lower Mammoth Creek from 1992-1994 may have been due to lower stream flows that prevailed in the basin during the extended six-year long drought (1987-1992) immediately prior to those years. Moyle et al. (1996) state that with a few exceptions, native non-game fishes in the Owens River Basin do not generally occur in streams above 4,900 feet elevation. Salamunovich (2009) suggested that the native fishes in lower Mammoth Creek (elevation 7,100-7,200 feet) are probably near the limits of their physical range and are able to expand their populations into higher elevation areas during those periods when stream flows remain low for extended periods of time. Examination of potential relationships between standardized abundance estimates of Owens sucker and tui chub and expressions of both High and Low flow at OMR and the OLD395 gages did not result in the identification of statistically significant relationships. Clearly, however, native fishes were more abundant from 1992-1994 than during later years.

Salamunovich (2009) further suggested that possible Owens sucker and tui chub population expansion may also be a response to reduced predation pressure from resident trout during drought periods. Multiple regression examination of the relationships between Owens sucker and tui chub abundance, and the abundance of brown and rainbow trout, did not identify statistically significant relationships over the 17-year period of analysis. Nonetheless, the series of 17 annual standardized abundances of Owens sucker and tui chub indicate that the highest abundances of both species occurred in the years 1992 through 1994 when trout abundances in Reach E were relatively moderate to low. Conversely, low to very low Owens sucker and tui chub abundances occurred in the years 1997, 1999, 2000 and 2007 when the Reach E abundances of brown and/or rainbow trout were at their highest.

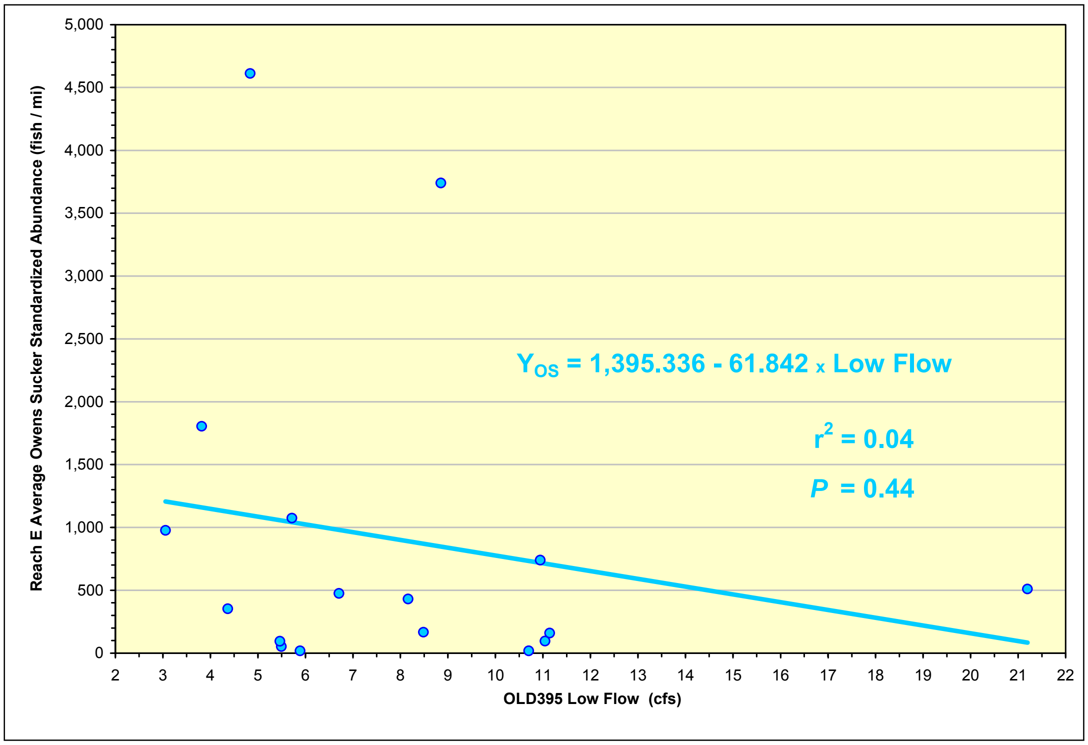

Figure E-12. Annual standardized abundance of Owens sucker (fish/mile) as a function of OLD395 Low Flow (cfs) and corresponding fitted linear regression line for the period 1988 through 2008.

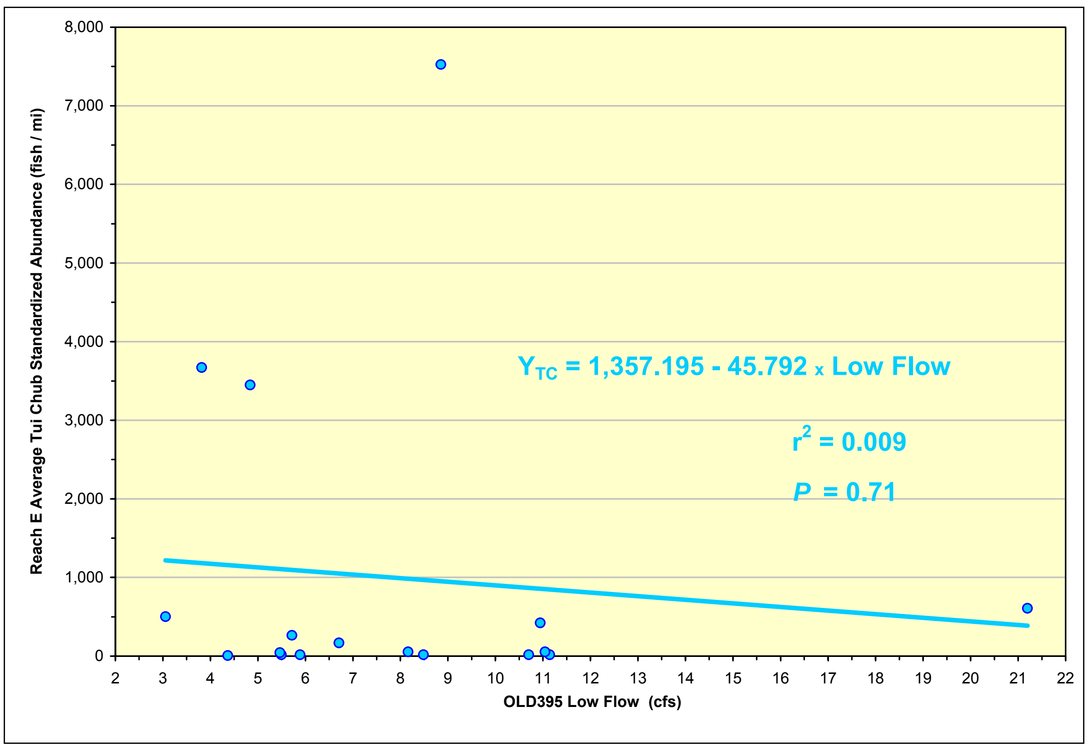

Figure E-13. Annual standardized abundance of Owens tui chub (fish/mile) as a function of OLD395 Low Flow (cfs) and corresponding fitted linear regression line for the period 1988 through 2008.

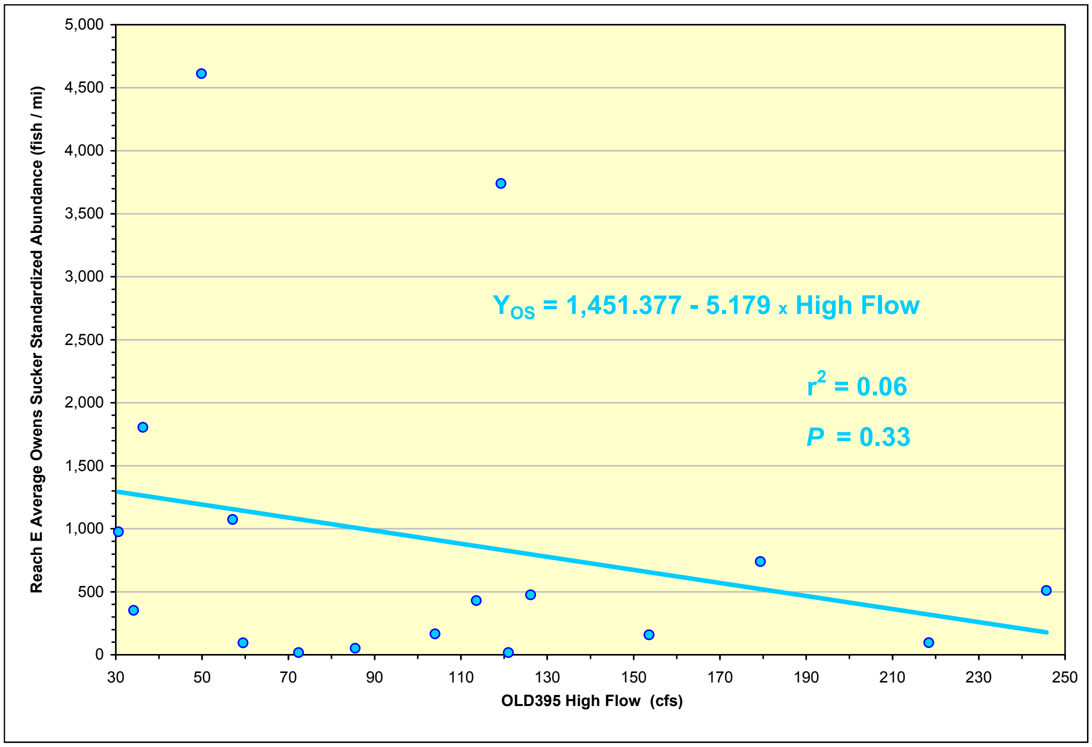

Figure E-14. Annual standardized abundance of Owens sucker (fish/mile) as a function of OLD395 High Flow (cfs) and corresponding fitted linear regression line for the period 1988 through 2008.

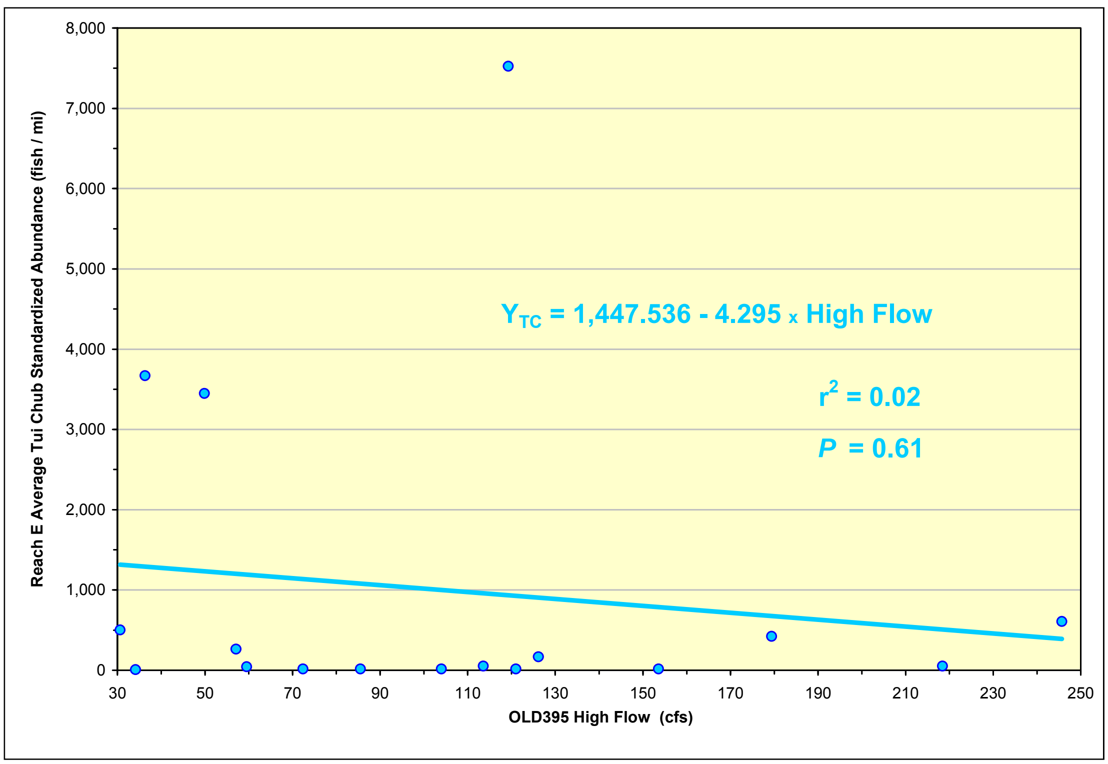

Figure E-15. Annual standardized abundance of Owens tui chub (fish/mile) as a function of OLD395 High Flow (cfs) and corresponding fitted linear regression line for the period 1988 through 2008.

5.2 STANDARDIZED TROUT ABUNDANCE

5.2.1 RAINBOW TROUT

For the 17-year period of record, the overall annual abundance of "wild" rainbow trout averages 370 fish per mile (**Table E-9**). By far, the highest annual average was during 2000, when about 4.5 times the annual average number of "wild" rainbow trout per mile (1,377) were present, relative to overall annual average (307 trout per mile) for the remaining 16 years of monitoring. Overall average annual abundance (number/mile) of "wild" rainbow trout was generally highest in the reaches (C and D) located in the "middle" of Mammoth Creek.

Table E-9. Standardized abundance estimates[1] (number/mile) for "wild" rainbow trout captured at each of the Mammoth Creek electrofishing sites, 1988-2008. Bold numbers indicate the highest value for each site.

	Sample Site								
	BH	BL	CH	CL	DH	DL	EH	EL	Annual Mean
2008	617	0	69	17	95	340	718	309	271
2007	680	55	121	83	421	428	222	168	272
2006	819	110	282	239	413	359	902	366	436
2005	493	282	70	0	158	158	211	475	231
2004	422	246	123	35	229	246	88	18	176
2003	669	194	106	35	211	282	176	0	209
2002	**1,038**	**810**	141	123	528	475	229	18	420
2001	616	106	88	722	563	422	493	18	378
2000	35	616	405	**6,354**	528	669	**2,253**	158	**1,377**
1999	123	669	546	1,179	686	510	334	194	530
1997	123	123	810	845	722	**1,021**	810	88	568
1996	282	18	**1,690**	528	**933**	229	458	**563**	587
1995	158	0	53	59	18	88	53	194	78
1994	18	0	581	1,654	387	616	106	0	420
1993	18	0	70	0	299	35	53	18	62
1992	70	0	141	651	546	229	141	0	222
1988	53	0	106	0	106	158	53	0	59
1988-2008	367	190	318	737	402	369	429	152	370

[1] Modified (by the incorporation of 1988 data) from Salamunovich (2009).

Visual examination of potential temporal trends in the average annual abundance (number/mile) of "wild" rainbow trout was facilitated by locally weighted regression smoothing obtained with S-plus© function loess (**Figure E-16**). Examination of Figure E-16 suggests that "wild" rainbow trout abundance (fish/mile) is somewhat cyclic over the 17-year period of record. The locally weighted regression smoothing suggests a period of increasing abundance from 1995 to 2000. From 2001, "wild" rainbow trout abundance declined to 2004. During the last 4 years, "wild" rainbow trout appear to have undergone a new period of increasing abundance until 2006, followed by a decrease during 2007 and 2008. As previously mentioned, however, "wild" rainbow trout data must be interpreted with caution because of the confounding influences associated with the identification of "wild" versus hatchery rainbow trout, and the unaccounted for variation in hatchery planting practices and recreational angling harvest.

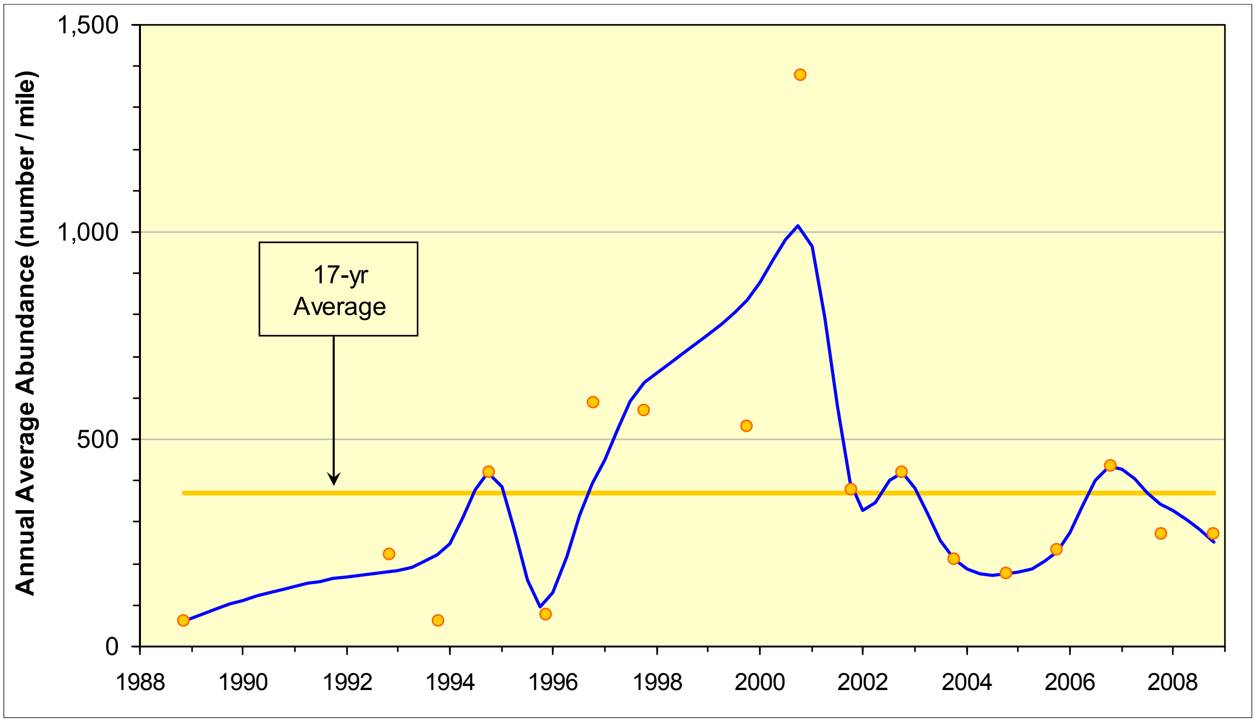

Figure E-16. Standardized average annual abundance estimates (number/mile) for "wild" rainbow trout during each year of monitoring, compared to the overall annual average abundance over the 17-year period of record. The blue line is the locally weighted regression smoothing of the standardized average annual abundance estimates obtained with S-plus© function loess (Span = 0.3).

5.2.2 BROWN TROUT

Relative to "wild" rainbow trout, brown trout are much more abundant in Mammoth Creek. For the 17-year period of record, the overall annual abundance of brown trout averages 1,555 fish per mile (**Table E-10**). Overall average annual abundance (number/mile) of brown trout is generally highest in the uppermost reach (Reach B) of Mammoth Creek.

Visual examination of potential temporal trends in the average annual abundance (number/mile) of brown trout (**Figure E-17**) also suggests a somewhat cyclic fluctuation about the long-term (17-year) average, as was suggested for "wild" rainbow trout. The average annual abundance of brown trout exhibits a decrease from 1994 through 1995, followed by a short period of increased abundance to 1997. From 1999 through 2005 brown trout abundance consistently declined. During 2006 and 2007, brown trout appear to have initiated a new period of increasing abundance followed by a decrease in 2008.

Table E-10. Standardized abundance estimates[1] (number/mile) for brown trout captured at each of the Mammoth Creek electrofishing sites, 1988-2008. Bold numbers indicate the highest value for each site.

	Sample Site								
	BH	BL	CH	CL	DH	DL	EH	EL	Annual Mean
2008	3,549	552	1,070	482	872	251	1,598	1,011	1,173
2007	4,949	238	1,691	731	3,142	**1,766**	**4,302**	**2,900**	**2,465**
2006	3,241	313	475	290	1,155	287	1,297	1,411	1,059
2005	1,320	792	634	194	387	862	669	563	678
2004	3,186	440	1,302	845	880	1,549	1,355	581	1,267
2003	2,869	458	**1,901**	933	616	1,426	1,390	616	1,276
2002	5,826	898	1,056	246	563	1,672	1,866	264	1,549
2001	4,717	1,707	1,496	246	1,144	1,162	1,461	528	1,558
2000	6,670	634	1,056	88	810	1,162	1,179	2,253	1,731
1999	5,333	1,338	1,707	299	2,200	616	2,182	2,200	1,984
1997	**8,589**	704	1,690	211	616	1,654	3,819	1,795	2,385
1996	4,858	158	1,302	158	1,901	634	898	1,144	1,382
1995	1,760	546	334	88	616	18	334	1,038	592
1994	4,171	2,253	810	528	**4,418**	1,584	2,464	405	2,079
1993	2,957	2,658	510	1,232	1,056	510	1,232	158	1,289
1992	3,045	1,848	563	845	1,390	1,584	3,978	194	1,681
1988	3,168	**4,699**	1,109	**1,901**	2,006	1,056	4,277	106	2,290
1988-2008	4,130	1,190	1,100	548	1,398	1,047	2,018	1,010	1,555

1 Modified (by the incorporation of 1988 data) from Salamunovich (2009).

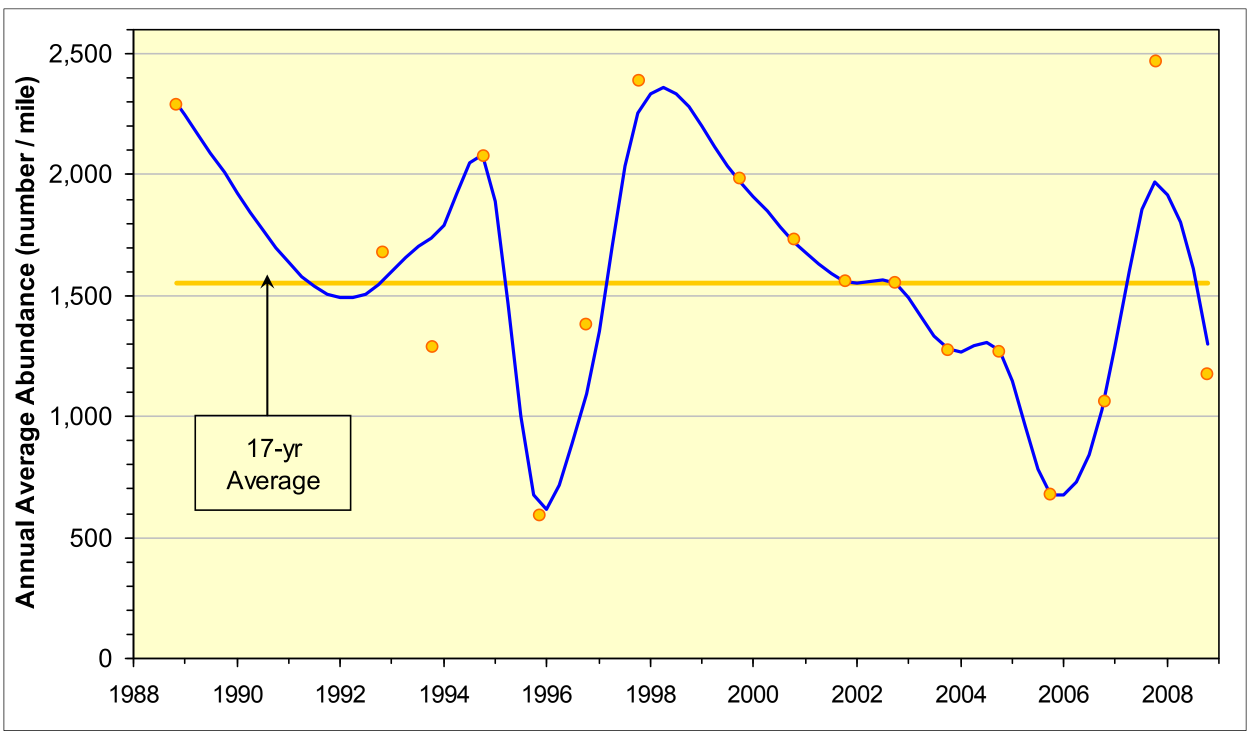

Figure E-17. Standardized average annual abundance estimates (number/mile) for brown trout during each year of monitoring, compared to the overall annual average abundance over the 17-year period of record. The blue line is the locally weighted regression smoothing of the standardized average annual abundance estimates obtained with S-plus© function loess (Span = 0.3).

5.3 TROUT LENGTH-FREQUENCY

Although site-specific variation in the abundance of size (and presumably age) classes is evident among years, multiple size classes of “wild” rainbow trout are present annually in Mammoth Creek over the 17-year period of record.[3] In general, most of the “wild” trout are represented by YOY size class fish. Examination of brown trout length-frequencies demonstrates that multiple size/age classes are generally present at all of the 8 sampling sites during the 17 annual fish surveys in Mammoth Creek. From the data included in Figure E-3, it is evident that the YOY size class dominates the brown trout populations in each reach of Mammoth Creek. Overall, the YOY size class comprised approximately 70% of all brown trout captured over the 17 years of sampling in Mammoth Creek. One potential contributor to the high percentage of YOY brown trout in the total population is the unaccounted for influence of recreational angling harvest on the larger (and older) size classes.

5.4 BROWN TROUT ABUNDANCE TEMPORAL TRENDS

Annual brown trout abundance estimates for Mammoth Creek and their 95% confidence intervals are displayed in **Table E-11**. The annual abundance estimates exhibit a slight decreasing trend over time which is extremely weak (r^2 =0.07) and non-significant (P =0.30) (**Figure E-18**).

Table E-12 displays the estimated annual abundances for all brown trout with fork lengths smaller that 120 mm, considered to be YOY brown trout, and their estimated 95% confidence intervals, in Mammoth Creek from 1988 through 2008. Annual YOY abundance estimates exhibit a decreasing trend which is extremely weak (r^2 =0.03) and non-significant (P =0.48) (**Figure E-19**).

5.5 YOY BROWN TROUT DENSITY TEMPORAL TRENDS

Annual YOY brown trout densities, expressed as fish/mile and averaged over the entire Mammoth Creek (i.e., $\bar{D}_{\mathrm{T}}$) exhibit a slight decreasing trend over time, although the trend is extremely weak (r^2 =0.04) and non-significant (P = 0.45) (**Figure E-20**). The reach- by-reach annual average densities also exhibit extremely weak decreasing trends, none of which are significant (**Figure E-21**).

[3] A discussion of site-specific variation in the abundance of “wild” rainbow trout size classes is presented for the 2006-2008 surveys in Salamunovich (2006, 2007 and 2009).

Table E-11. Annual brown trout estimated abundance and 95% confidence intervals in Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

YEAR	Abundance $\hat{Y}_T$	95% Confidence Interval
1988	20,516	(12,607; 33,389)
1989	---	---
1990	---	---
1991	---	---
1992	15,089	(9,033; 25,204)
1993	11,574	(6,802; 19,692)
1994	18,664	(11,236; 31,003)
1995	5,333	(2,793; 10,181)
1996	12,403	(5,896; 26,093)
1997	21,409	(9,853; 46,518)
1998	---	---
1999	17,815	(10,556; 30,063)
2000	15,543	(6,886; 35,086)
2001	13,983	(7,723; 25,316)
2002	13,904	(6,266; 30,850)
2003	11,455	(7,451; 17,610)
2004	11,376	(7,170; 18,049)
2005	6,083	(4,348; 8,510)
2006	9,539	(5,009; 18,167)
2007	22,476	(14,370; 35,152)
2008	10,803	(5,933; 19,671)

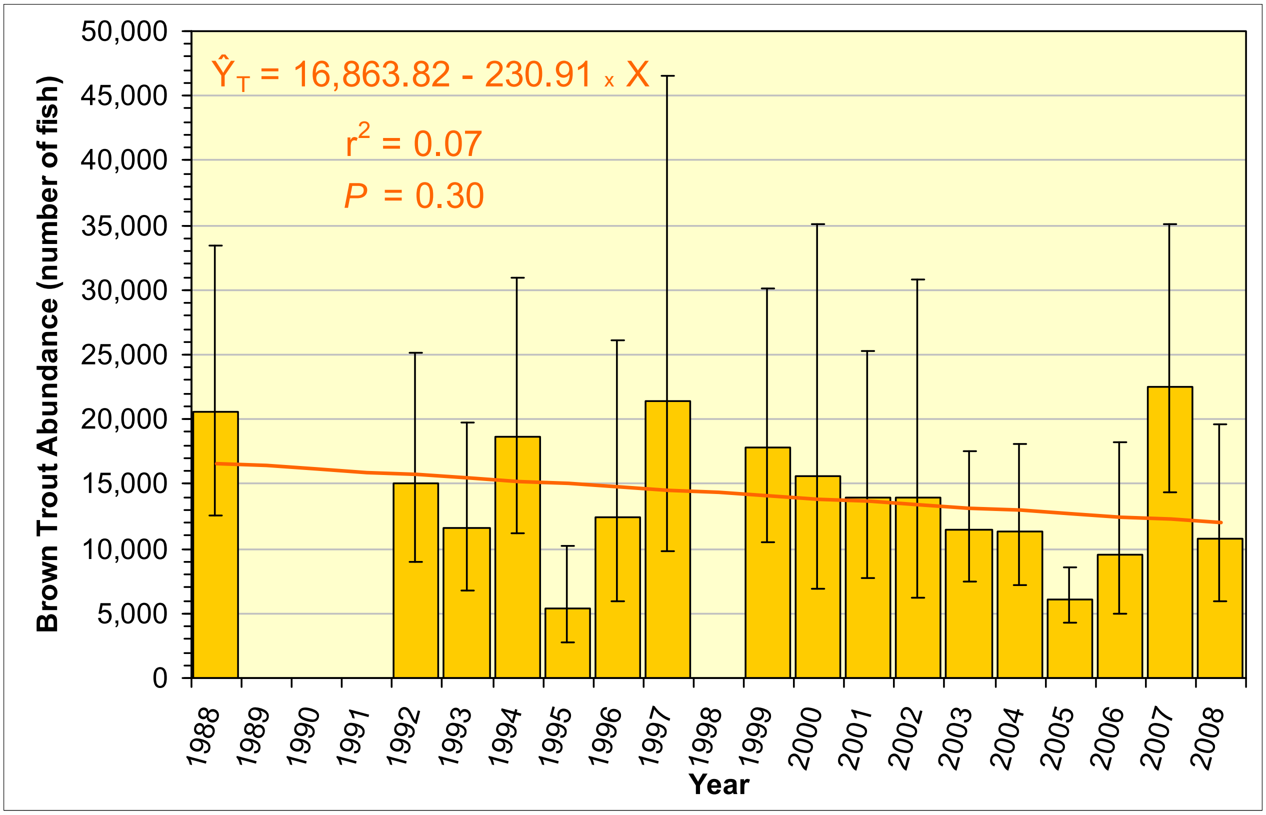

Figure E-18. Annual brown trout abundance estimates (bars), estimated 95% confidence intervals (error bars) and fitted regression line for Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

Table E-12. Annual YOY brown trout abundance and 95% confidence intervals for Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

YEAR	Abundance $\hat{Y}_T$	95% Confidence Interval
1988	15,195	(9,241; 24,985)
1989	---	---
1990	---	---
1991	---	---
1992	10,270	(5,419; 19,462)
1993	6,419	(4,005; 10,288)
1994	13,746	(7,675; 24,618)
1995	2,726	(1,623; 4,576)
1996	10,073	(4,279; 23,712)
1997	16,965	(7,021; 40,992)
1998	---	---
1999	12,956	(7,041; 23,841)
2000	12,561	(4,664; 33,828)
2001	11,593	(6,224; 21,595)
2002	10,310	(3,636; 29,232)
2003	8,196	(4,652; 14,441)
2004	7,051	(3,386; 14,681)
2005	3,417	(1,755; 6,651)
2006	6,834	(2,826; 16,522)
2007	19,138	(11,900; 30,778)
2008	6,439	(2,369; 17,501)

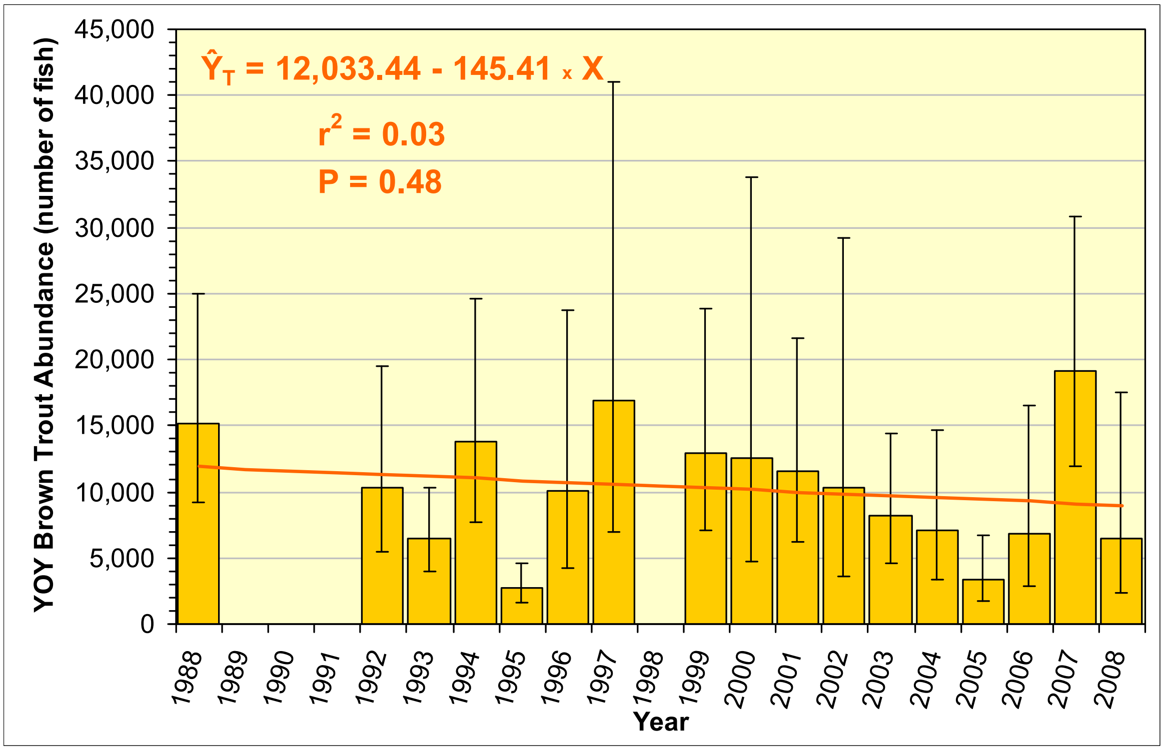

Figure E-19. Annual YOY brown trout abundance estimates (bars), estimated 95% confidence intervals (error bars) and fitted regression line for Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

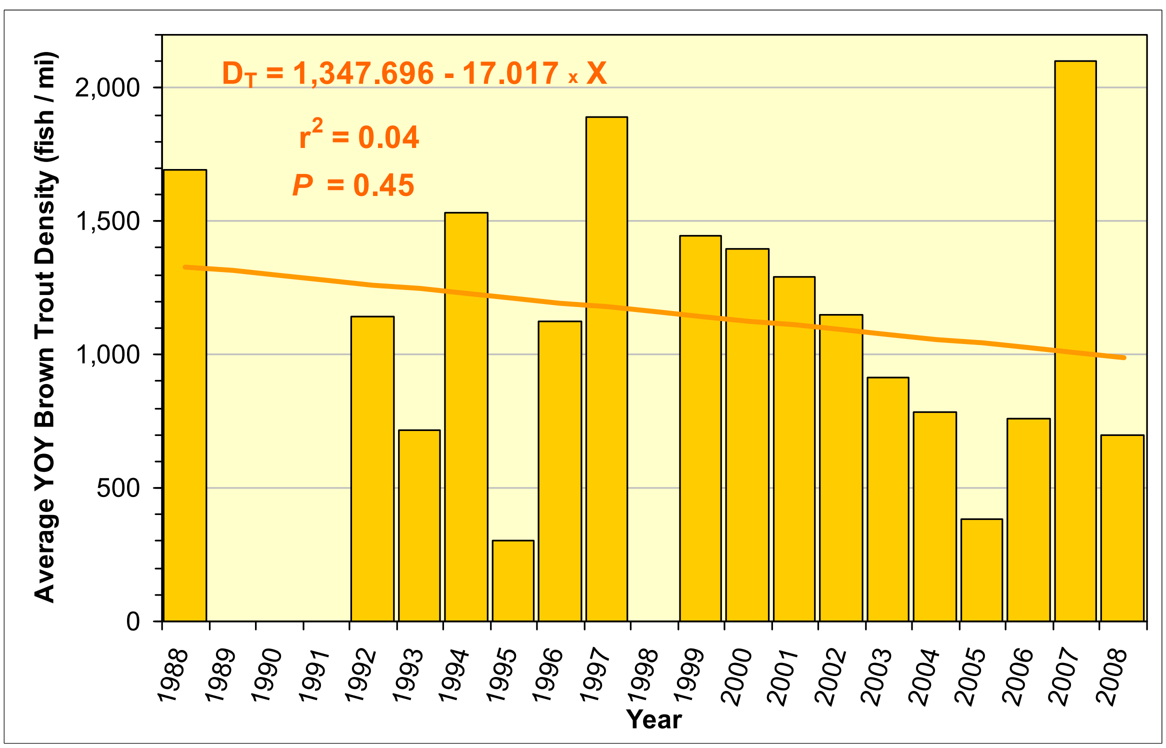

Figure E-20. Annual average YOY brown trout density estimates (bars) and fitted regression line for Mammoth Creek between Sherwin St. and the confluence with Hot Creek.

Figure E-21. Annual average YOY brown trout density estimates (bars) and fitted regression lines in the four surveyed reaches of Mammoth Creek from 1988 through 2008.

As previously discussed, additional trend analyses of YOY brown trout densities emphasized recent years (1999 through 2008). **Figure E-22** displays the non-significant (P = 0.47) and extremely weak (r^2 = 0.07) decreasing linear temporal trend in the annual average YOY brown trout densities over the period 1999 through 2008. The reach-by-reach trend analysis of annual average YOY brown trout densities over the period 1999-2008 (**Figure E-23**) indicates a weak to moderate decreasing linear trend that is significant for Reach B (r^2 =0.39, P = 0.05). By contrast, the remaining three reaches exhibit decreasing (Reach D) or increasing (Reaches C and E) but extremely weak trends in annual average YOY brown trout densities (r^2 ranging from 0.002 to 0.0001), none of which were significant (P ranging from 0.90 to 0.98).

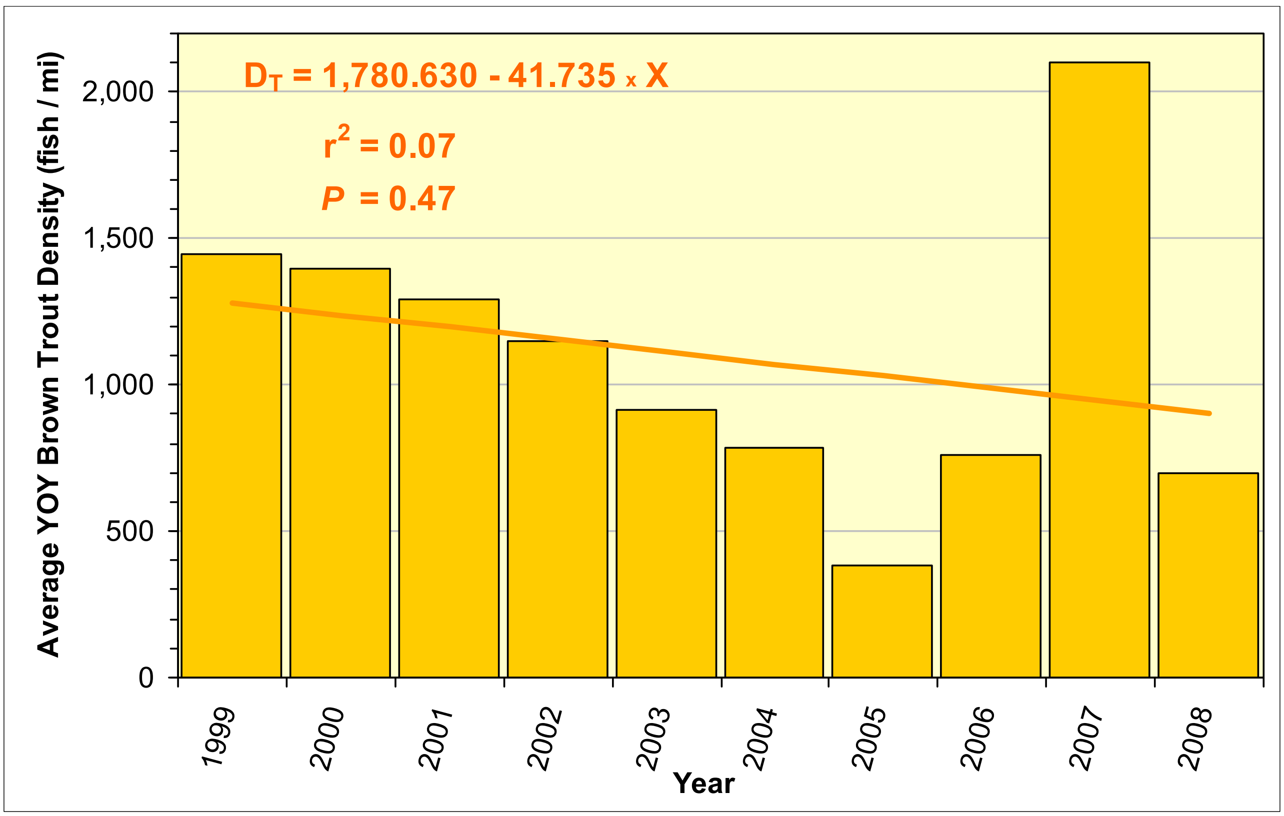

Figure E-22. Annual average YOY brown trout density estimates (bars) in Mammoth Creek and the fitted regression line for the period 1999-2008.

Because the recent annual average YOY brown trout densities displayed in Figure E-22 result from averaging the eight sample site densities (two per reach) of each year, and because the reach-by-reach trend analysis of annual average YOY brown trout densities displayed substantial differences among reaches (Figure E-23), the relative importance of each particular reach (and associated temporal trend) in the average annual densities for the entire creek was appraised by removing the annual densities of a particular reach, one at a time, recalculating annual average YOY brown trout densities for the creek (now based on only three reaches each year), and repeating the regression analysis to obtain corresponding temporal trends. **Figure E-24** displays the results of this evaluation.

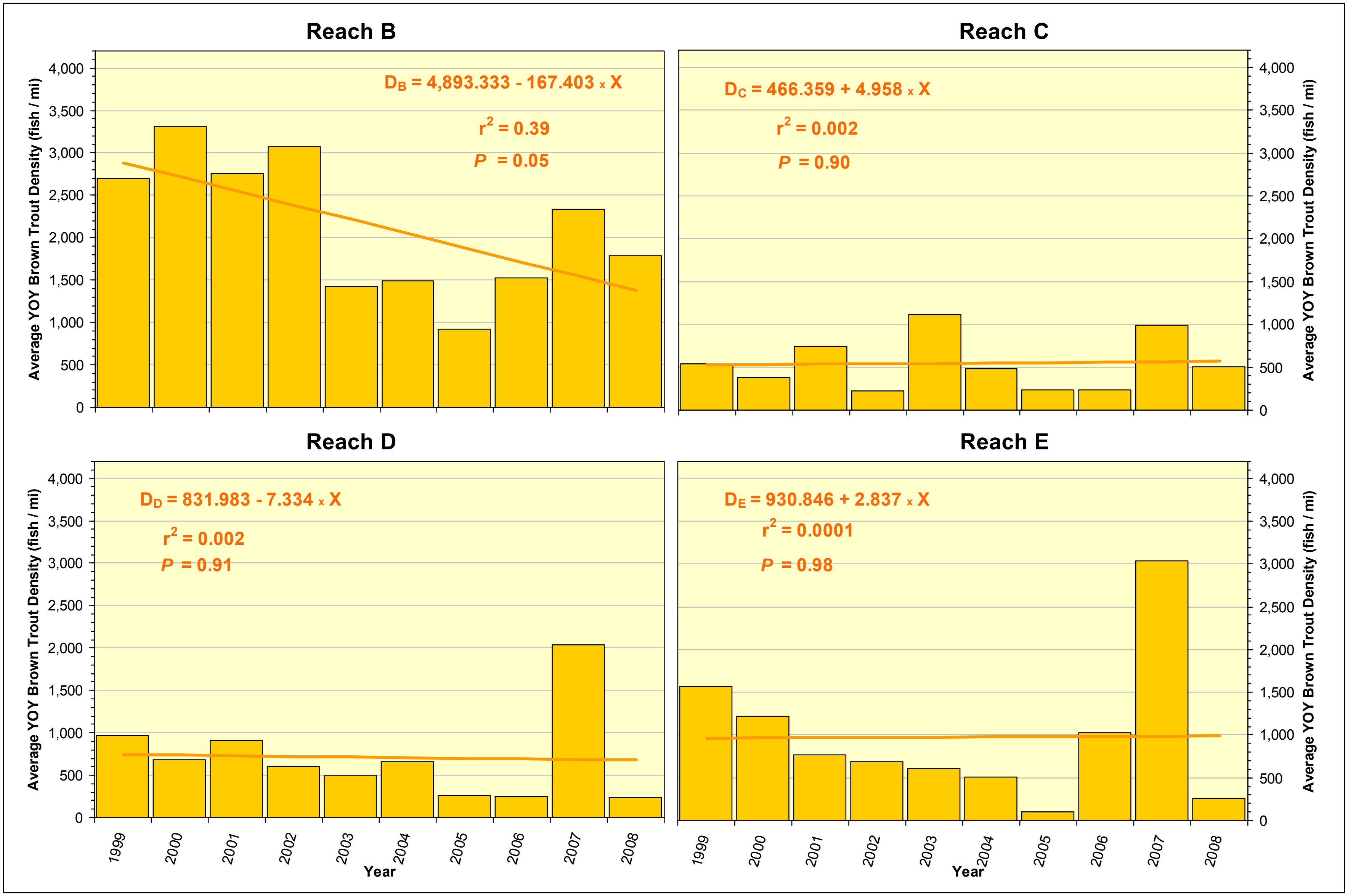

Figure E-23. **Annual average YOY brown trout density estimates (bars) and fitted regression lines in the four surveyed reaches of Mammoth Creek for the period 1999-2008**.

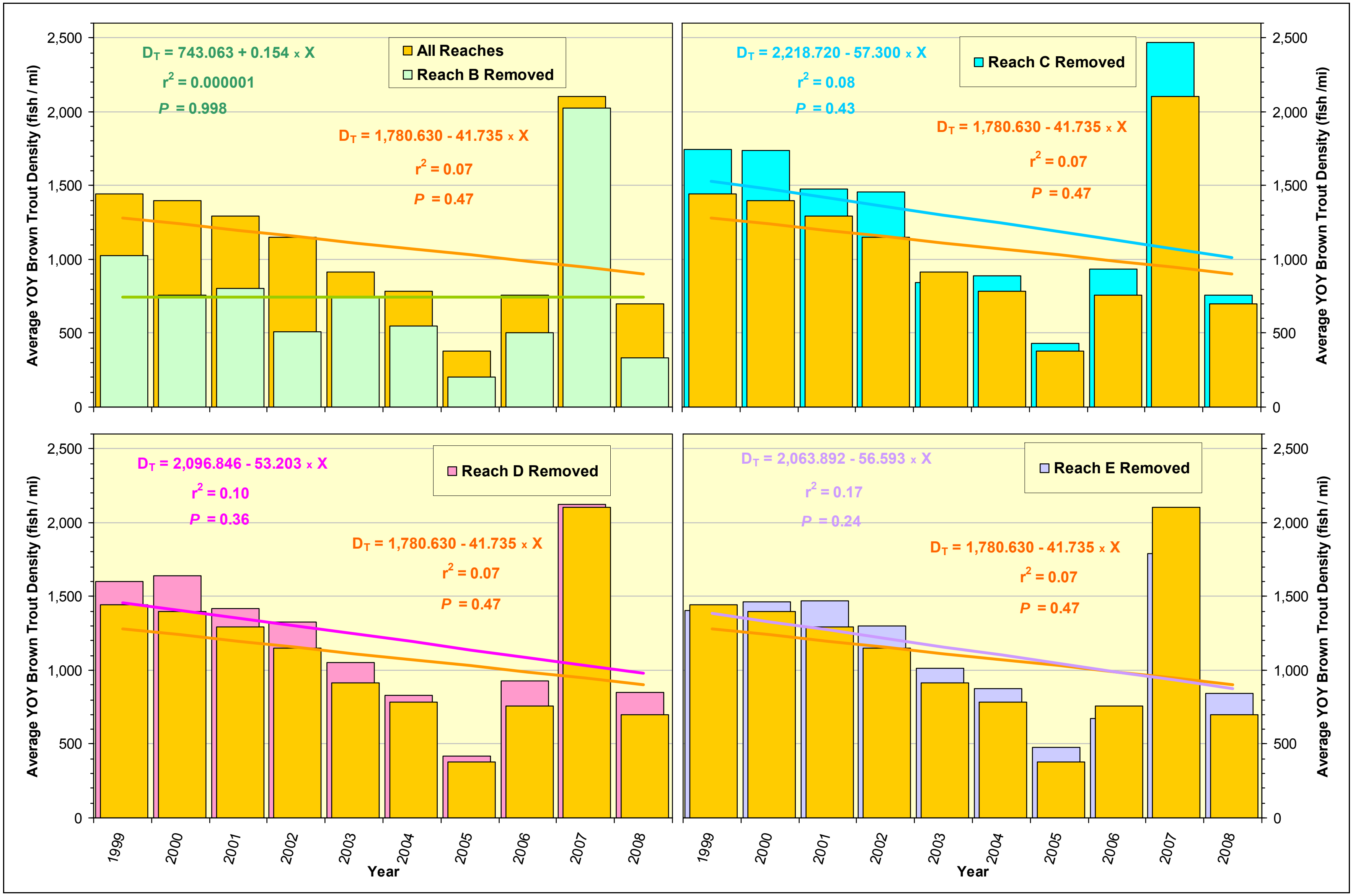

Figure E-24. Influence of annual average reach densities on annual average YOY brown trout density trends in Mammoth Creek during 1999-2008. Orange bars and regression lines indicate the trend of creek annual average YOY brown trout density with all sampled reaches; bars and lines in green, blue, pink and violet indicate the trends of the creek average density after removing densities from Reaches B, C, D and E, respectively.

The estimated decreasing trends (i.e., the regression slopes) are particularly affected when the annual YOY brown trout densities of Reach B are removed. When the relatively high annual densities of Reach B that display a moderate to weak decreasing trend (see Figure E-23) are removed from the annual averaging, the resulting creek annual average YOY brown trout densities (green bars) display a nearly horizontal and very weak increasing temporal trend. This result indicates that, due to the relatively high densities of YOY brown trout in Reach B, combined with the moderate to weak, but significant decreasing trend in YOY density in Reach B from 1999 through 2008, the overall slight declining trend in YOY density in Mammoth Creek in recent years is most strongly influenced by Reach B. The removal of the annual densities of Reach C, D or E does not appear to substantially affect the temporal trends of the resulting creek annual average YOY brown trout densities in recent years (see blue, pink and violet bars and lines in Figure E-24).

5.6 POTENTIAL RELATIONSHIPS BETWEEN YOY BROWN TROUT DENSITY AND FLOW

The annual average YOY brown trout densities for all reaches of Mammoth Creek during the period 1988 through 2008 were regressed against OMR low flow quartile to assess potential relationships between the annual densities and the low Mammoth Creek flows of late summer and autumn, which precede the surveys each year. The linear regression suggests that the annual average YOY brown trout densities are negatively correlated with low Mammoth Creek flows (**Figure E-25**). In other words, the observed distribution of the data set and resultant slope of the linear regression suggest that YOY brown trout density decreases as the flows during the summer/autumn period increase. However, the relationship is not significant (P = 0.12) and weak (r^2 = 0.15).

The annual average YOY brown trout densities for all reaches of Mammoth Creek during the period 1988 through 2008 also were regressed against the lowest average monthly OMR flows (among August, September, and October) for each year to assess potential relationships between the annual densities and the low Mammoth Creek flows of late summer and autumn, which precede the surveys each year. As described for the regression using the low flow quartile as the explanatory variable each year, the linear regression suggests that the annual average YOY brown trout densities are negatively correlated with the lowest average monthly Mammoth Creek flows at the OMR Gage (**Figure E-26**). As previously discussed, the observed distribution of the data set and resultant slope of the linear regression suggests that YOY brown trout density decreases as the flows during the summer/autumn period increase. This relationship is highly significant (P = 0.01) and weak to moderate (r^2 = 0.34).

The annual average YOY brown trout densities for the entire Mammoth Creek during the period 1988 through 2008 also were regressed against OMR High Flow to assess potential relationships between the annual fall densities and the peak Mammoth Creek flows of the preceding late spring/early summer. The linear regression suggests that the annual average YOY brown trout densities are negatively correlated with the Mammoth Creek late spring/early summer peak flows (**Figure E-27**). The linear relationship was weak to moderate (r^2 = 0.34), and highly significant (P = 0.01). In other words, the highly significant negative correlation between annual average YOY brown trout density and peak runoff flows during late spring/early summer indicate that high peak flows are associated with low YOY brown trout densities the following autumn. Presumably, high peak runoff flows may scour the streambed and result in the dislodgement of incubating embryos, and/or flushing or displacement of post-emergent YOY brown trout from their habitats.

As previously mentioned, it has been speculated that streambed cleansing (via scouring flows) may result in additional substrate interstitial space availability for the colonization of benthic macroinvertebrates. It was further suggested that these potentially "improved" habitat conditions (i.e., increased macroinvertebrate production as a food supply) for YOY trout rearing may not be evident in YOY trout densities within a year due to potential embryo dislodgement, or flushing (or displacement) of YOY trout from their habitats, but may be reflected by YOY trout densities in the subsequent year. To examine this potential phenomenon, OMR High Flow variables were lagged backward by one year, then regressed against the annual average YOY brown trout densities for the entire creek for the 17-year period of record. The observed distribution of the data set and resultant slope of the linear regression suggest that YOY brown trout density increases with an increase in peak runoff flow that occurred 1 year previously (**Figure E-28**). Although the relationship is significant (P = 0.02), it is weak to moderate (r^2 = 0.30).

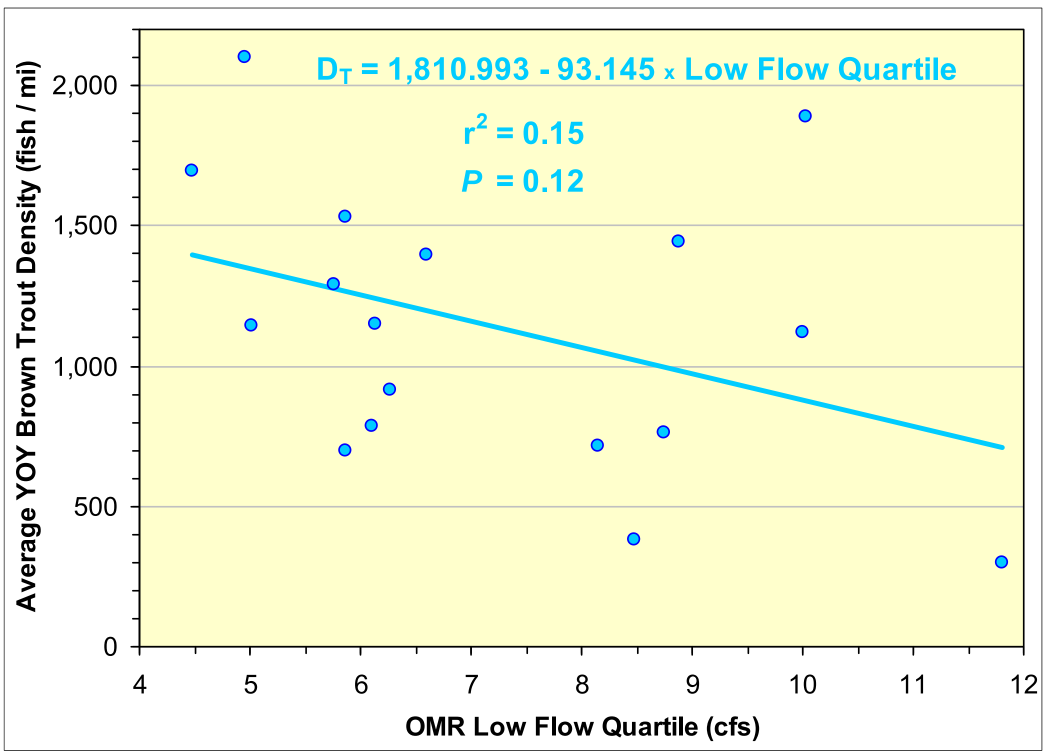

Figure E-25. Annual Mammoth Creek average YOY brown trout density as a function of OMR Low Flow Quartile and corresponding fitted linear regression line for the period 1988 through 2008.

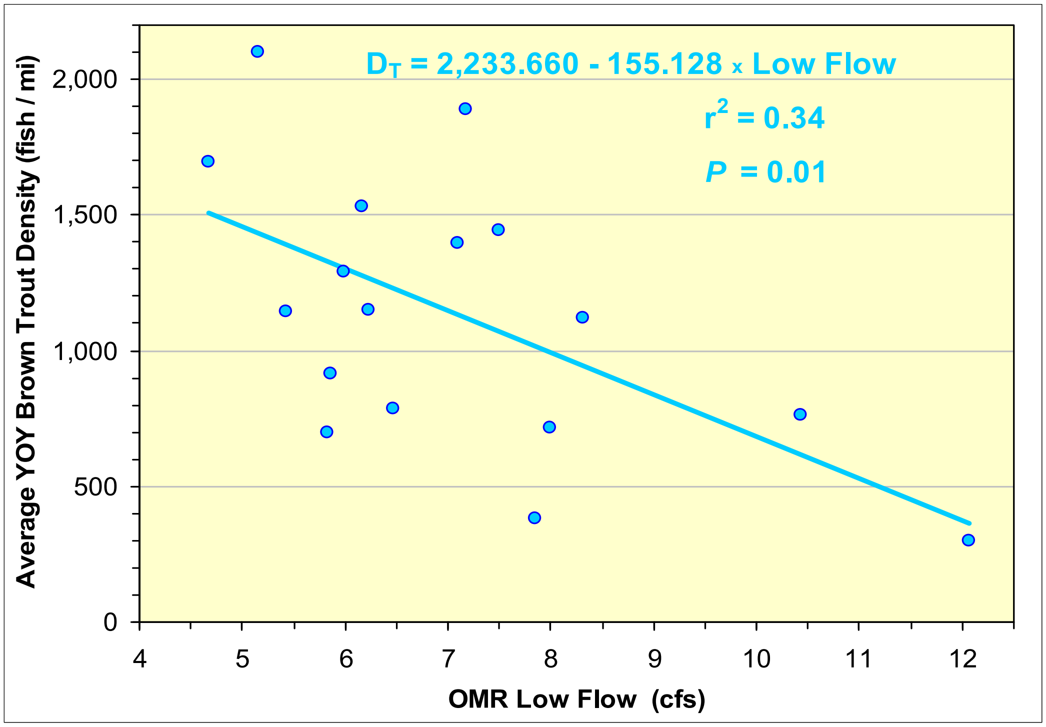

Figure E-26. Annual Mammoth Creek average YOY brown trout density as a function of OMR Low Flow and corresponding fitted linear regression line for the period 1988 through 2008.

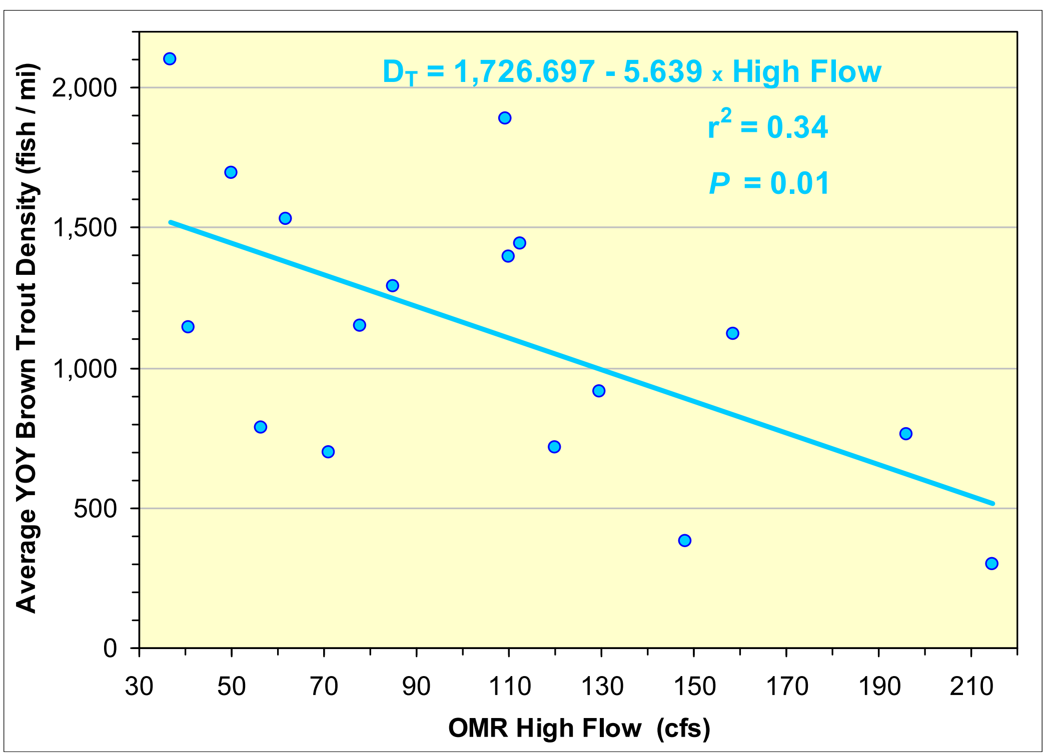

Figure E-27. Annual Mammoth Creek average YOY brown trout density as a function of OMR High Flow and corresponding fitted linear regression line for the period 1988 through 2008.

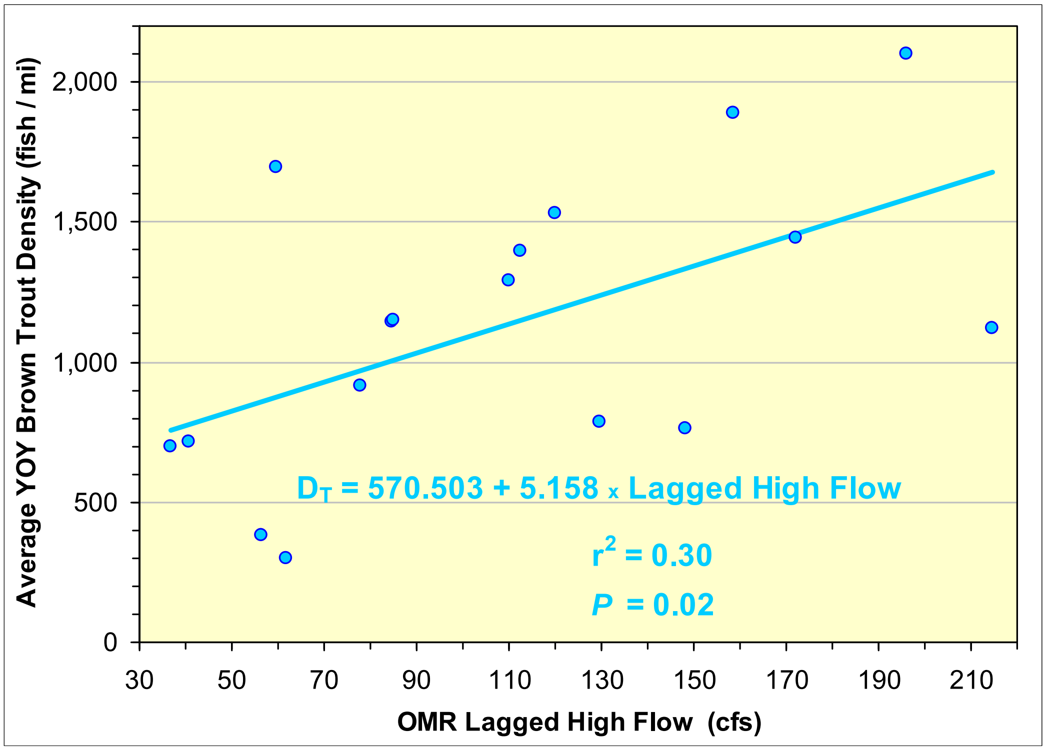

Figure E-28. Annual Mammoth Creek average YOY brown trout density as a function of one-year-lagged OMR High Flow and corresponding fitted linear regression line for the period 1988 through 2008.

6.0 DISCUSSION – CALIFORNIA FISH AND GAME CODE SECTIONS 5937 AND 5946

California Fish and Game Code (Sections 5937 and 5946) stipulates that the owner of a dam is required to allow sufficient water to pass the dam in order to keep fish[4] in the stream below the dam in good condition. Mammoth Community Water District is obligated to meet this requirement. The term "good condition" although not well defined, implies a variety of biotic and abiotic factors that influence the aquatic community. CDFG's testimony before the State Water Resources Control Board regarding the maintenance of fish in good condition and stream flow requirements in streams tributary to Mono Lake was as follows:

> *"[t]he instream flows necessary to keep fish in good condition include those which will maintain a self-sustaining population of desirably-sized adult vertebrate fish which are in good physical condition i.e. well proportioned, and disease-free. Fish populations should not be limited by lack of cover, food availability, poor water quality (including temperature), or lack of habitat necessary for reproduction. The fish populations should contain good numbers of different age classes, and habitat for these life stages should not be limiting.*

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[4] The term "fish" as defined in California Fish and Game Code Section 45 includes both vertebrate and invertebrate aquatic life.

> *Therefore, the "good condition" requirement must include the protection and maintenance of the physical, geological, and chemical parameters that constitute the ecology of the stream. The ecological health of the stream will determine if fish, both vertebrates and invertebrates, are to be kept in good condition.'*[5]

As discussed in MCWD and USFS (2000), CDFG's definition focuses on the ecological heath of the stream as the indicator of good condition, and identifies the factors that indicate ecological health. These factors include: (1) attributes of the fish population such as a self-sustaining population with multiple age classes and appropriate abundance, in good physical condition; and (2) various stream characteristics including availability of food, cover, habitat, suitable water quality conditions, and the maintenance of these conditions. This definition also specifies that invertebrates as well as vertebrate fish are to be maintained in good condition (MCWD and USFS 2000).

6.1 ABUNDANCE

Data obtained over the 17 years of fish community survey surveys in Mammoth Creek demonstrate considerable variation in trout abundance among years, and among sample sites within years. Variation in trout abundance is most likely in response to variable environmental conditions (e.g., stream flows, habitat availability and suitability), variable biologic responses (e.g., reproductive success, over-winter survival, food availability, growth, year-class strength and recruitment potential), and variable anthropogenic influences (e.g., hatchery stocking practices, recreational angling, land use and development).

Insight to the recent status of trout abundance in Mammoth Creek can be gained by comparison to estimates of abundance in nearby creeks during the 1970s and 1980s, prior to development in the Mammoth Lakes Basin (particularly in the Town of Mammoth Lakes) and the increased recreational use that has occurred over about the last three decades.

Although the overall lack of complete and accurate measurement of fish weights and sample site areas prohibit the accurate calculation of area-based biomass (i.e., fish pounds per acre) for previous survey years, Salamunovich (2006, 2007, 2009) reported biomass estimates for the 2006, 2007 and 2008 fish surveys. He reported that seven of the eight sample sites in Mammoth Creek range from 11-20 feet in width, and in 2006 provided an average wild trout (both brown and rainbow) biomass estimate of 92.9 pounds per acre, which ranged from a low of 46.5 pounds per acre at site CL to a high of 156.5 pounds per acre at site DH. In 2007, those seven sites provided an average wild trout biomass estimate of 96.6 pounds per acre, and ranged from a low of 27.7 (site CL) to a high of 143.8 pounds per acre (site DH), while in 2008 they provided an average wild trout biomass estimate of 81.5 pounds per acre, and ranged from a low of 25.9 (Site CL) to a high of 140.2 pounds per acre (Site EL). These biomass estimates exceed the approximate 33 to 35 pounds per acre for similarly-sized Sierra streams reported by Gerstung (1973). The eighth sample site (BL) in Mammoth Creek was characterized by a mean width of less than 10 feet, and provided wild trout biomass estimates of 70 pounds per acre during 2006, 35.0 pounds per acre during 2007, and 57.9 pounds per acre during 2008, which were respectively 100, 50 and 83 percent of Gerstung's biomass estimate for streams of similar sizes (Salamunovich 2006, 2007, 2009).

[5] Taken from CDFG testimony at SWRCB hearings for Mono Lake and the Mono Basin in September 1990 (from MCWD and USFS 2000).

CDFG conducted a survey of fish populations in streams of the Owens River drainage in 1983 and 1984 (Deinstadt et al. 1985). Fish populations were estimated within pre-selected sampling sections and then, based upon the length of each individual sampling section, directly extrapolated and expressed as the number of trout per mile. In creeks near Mammoth Creek, CDFG estimated from 877 to 4,822 brown trout per mile in four sections of Convict Creek, and from 600 to 1,109 brown trout per mile in McGee Creek. In addition to nearby creeks, CDFG also estimated brown trout abundance in Mammoth Creek itself. CDFG's estimates for five sections of Mammoth Creek ranged from 493 to 2,798 brown trout per mile. By comparison, although subject to inter-annual variability, annual average abundance of brown trout at individual sample sites ranges from 548 brown trout per mile at sample site CL to 4,130 brown trout per mile at sample site BH, with an overall average of 1,555 per mile for the recent 17-year period of monitoring. These comparisons indicate that brown trout abundance in recent years is comparable to abundance estimates from over 20 years ago in nearby creeks, as well as from Mammoth Creek itself.

Rainbow trout also exhibit inter- and intra-annual (among site) variability in abundance in Mammoth Creek, and are much less abundant than brown trout. Examination of the data suggests that "wild" rainbow trout abundance (fish/mile) is somewhat cyclic over the 17-year period of record, with generally distinguishable 4-5 year cycles when "wild" rainbow trout abundance fluctuates about the long-term (17-year) average. "Wild" rainbow trout abundance increased from 2004 through 2006, and decreased in 2007 and 2008. As previously mentioned, however, "wild" rainbow trout data must be interpreted with caution because of the problems associated with the identification of "wild" versus hatchery rainbow trout, the unaccounted for variations in hatchery planting practices, and recreational angling harvest.

6.2 RESILIENCE

Population resilience (i.e., the ability of the population to recover from episodic environmental events that reduce population numbers) also is an important indicator of the condition of the population and the quality of the habitat. Fish populations with relatively high reproductive potential that inhabit streams where spawning habitat is not limiting can recover quickly from short-term reductions in numbers and maintain a relatively stable long-term population. By contrast, populations with low reproductive potential or that occupy streams where spawning habitat, or habitat for early life stages is limiting, may remain depressed for longer periods following isolated events that reduce population numbers (MCWD and USFS 2000).

For the 17 years of fish survey data, the brown trout abundance indicators of annual average abundance (number per mile) and YOY density (number/mile) for Mammoth Creek exhibit considerable inter-annual variation. Examination of the data demonstrates that the brown trout population has the ability to recover (i.e., exhibit increased abundance) relatively quickly following episodic reduced abundance levels in specific years. For example, the lowest abundance among all 17 years of sampling for all brown trout, as well as for YOY brown trout, occurred in 1995. However, by 1997 the second highest abundance of brown trout (and YOY brown trout) occurred, over a four-fold increase over 1995 levels. The second-lowest year of brown trout abundance occurred in 2005, yet the abundance of all brown trout and of YOY brown trout increased substantially in 2006, and in 2007 achieved over a four-fold increase of 2005 levels, for the highest annual abundance of all 17 years. These trends indicate the resiliency of the brown trout populations in Mammoth Creek.

6.3 SIZE/AGE STRUCTURE

Examination of brown trout length-frequencies demonstrates that multiple size/age classes were generally present during each of the 17 annual fish surveys in Mammoth Creek. From the data included in Figure E-3, it is evident that the YOY size class dominates the brown trout populations in each reach of Mammoth Creek. Overall, the YOY size class comprised approximately 70% of all brown trout captured over the 17 years of sampling in Mammoth Creek.

The largest group each year most likely represents YOY fish from 50 to 120 mm in fork length (FL), the group from about 120 to about 180 mm FL probably represents Age I fish, the group from about 180 to 260 mm FL are most likely Age II fish, and fish in the 260 to 320 mm FL size range may represent Age III fish. Older fish may be represented by the few fish captured that were larger than 320 mm (up to 462 mm) FL.

Although ages of fish were not directly estimated from these studies, the observed length groups correspond well with previous investigations. Average length at annulus formation for brown trout in east slope Sierra Nevada streams has been reported to range from 84-139 mm FL (Age I) 160-257 mm FL (Age II), and 252-318 mm FL (Age III) (Snider and Linden 1981). In nearby Hot Creek, the average length at annulus formation was reported to range from 133-157 mm FL (Age I), 227-243 mm FL (Age II), and 291-317 mm FL (Age III) (Snider and Linden 1981).

Available data demonstrate that Mammoth Creek supports a self-sustaining population of brown trout of multiple size/age classes, including adult-sized fish.

6.4 PHYSICAL CONDITION

The previously described CDFG interpretation of "good condition" included fish in good physical condition (i.e., well-proportioned and disease-free). Over the 17 years of fish community surveys in Mammoth Creek, general reporting of visual examination of fish for external indicators of disease or fish "health" (i.e., lesions, tumors, parasites) is lacking. However, physical condition in terms of physiologic proportion, expressed as Fulton's Condition Factor (K), is reported for the first and last three survey years. The condition factor compares an individual fish's weight-length relationship, with values of 1.0 or more generally considered normal for a healthy trout population (Salamunovich 2009).

For the earliest (1988) survey, 93 percent of all brown trout collected exhibited condition factors equal to or exceeding a value of 1.0. For the 2006 survey, reported condition factors for both brown and "wild" rainbow trout at all sampling sites were well above the 1.0 "healthy" trout level (Salamunovich 2006). For the 2007 survey, 97 percent of all brown trout and "wild" rainbow trout collected, and for the 2008 survey, 98 percent of all brown trout and 95 percent of all "wild" rainbow trout collected exhibited condition factors equal to or exceeding a value of 1.0. Thus, available information indicates that resident trout, particularly brown trout, in Mammoth Creek are in good physical condition.

6.5 HABITAT

Habitat considerations also were included in CDFG's interpretation of good condition – specifically, that fish populations should not be limited by lack of cover, poor water quality (including water temperature), or lack of habitat necessary for reproduction.

Fish cover can be characterized as instream cover including factors such as surface water turbulence, instream object cover (hydraulic roughness elements generally in the form of large substrates or woody material), undercut banks, aquatic vegetation, and overhanging vegetation proximate to the water surface. Fish cover also can be characterized as riparian vegetation and its associated canopy cover. Although the dominant cover type varies among sample sites, all of the sample sites contain some forms of instream cover (Salamunovich 2006). With the exception of the lowest reach (Reach E), which is in active pastureland, Mammoth Creek supports riparian communities (MCWD and USFS 2000). As previously discussed, anecdotal observations suggest that riparian cover may have increased at certain sampling sites since 1988 through the establishment of willows.

Available water temperature information for Mammoth Creek is presented in MCWD and USFS (2000), and this brief summary of water temperature considerations is taken directly from that report. Water temperature data collected during 1988 and 1989 at various locations indicate that water temperature in Mammoth Creek fluctuates daily, with the magnitude of the fluctuation dependent upon location and time of year. Daily temperature fluctuations were lowest in the upstream sections of the creek (about 5 to 9°F at Sherwin Street) and greatest in Reach E (about 16 to 23°F). The maximum daily fluctuations occurred during the summer months; daily fluctuations were nearly nonexistent during the winter months when water temperature during the entire winter period was near 32°F. Maximum daily temperature also varied by location and time of year. The highest maximum daily water temperatures occurred in the downstream sections (Reaches D and E) during the summer, with temperatures of about 68°F recorded on occasion.

Mammoth Community Water District collected additional water temperature data in 1992 from two locations: near the Old Highway 395 crossing (Reach D); and near the confluence with Hot Creek (Reach E in Chance Meadow). These temperature records provided results similar to those found in 1988. The highest maximum daily water temperatures occurred during the summer, with temperatures of about 68°F recorded on occasion near Old Highway 395 and temperatures near 79°F occasionally recorded in Chance Meadow.

As reported by MCWD and USFS (2000), water temperatures recorded in Mammoth Creek during 1988 and 1989 were generally within the optimal ranges reported for fry, juvenile, and adult life stages of brown trout during the summer, and were less than optimal but generally within the tolerance range during fall and spring. Water temperatures during winter were generally at or slightly below the reported tolerance range for all life stages. High water temperatures do not appear to be a significant problem in Mammoth Creek. For example, the upper limiting, near lethal water temperature for adult brown trout was reported at 27.2°C, or about 81°F (Needham 1969 *as cited in* MCWD and USFS 2000). At this temperature, naturally reproducing, viable stream populations would not be maintained (Raleigh et al. 1986; Needham 1969 *as cited in* MCWD and USFS 2000). Review of the information presented in MCWD and USFS (2000) also suggests that maximum daily water temperatures in the lowermost section of Mammoth Creek near its confluence with Hot Creek can reach stressful levels during the summer, although those temperatures are present only for relatively short periods due to the substantial diurnal fluctuations.

Finally, it is clear that habitat necessary for reproduction is not lacking in Mammoth Creek. The dominance of YOY trout each year of the 17 annual surveys demonstrates successful reproduction.

Available information indicates that the trout populations in Mammoth Creek, particularly the brown trout populations, are not limited by lack of cover, poor water quality (including water temperature) or lack of habitat necessary for reproduction.

6.6 MACROINVERTEBRATES/FISH FOOD AVAILABILITY

The previously described CDFG interpretation of maintaining "good condition" addresses the macroinvertebrate community, and the term "fish" as defined in California Fish and Game Code Section 45 includes both vertebrate and invertebrate aquatic life. A thorough examination and discussion of available benthic macroinvertebrate community information for Mammoth Creek is presented in Attachment A. Following is a brief summary of that information.

MCWD and USFS (2000) reported that the aquatic invertebrate sampling conducted from 1992 to 1994 suggests that the aquatic invertebrate community in Mammoth Creek is relatively healthy, being composed of a relatively large number of taxa (around 20), representing a number of different families (around 15), and with good representation of the more sensitive taxa within the EPT orders.

Subsequent benthic macroinvertebrate (BMI) sampling conducted as a requirement of the Hot Creek Hatchery NPDES permit from 2000 through 2004 indicated that six of twelve metrics strongly support the hypothesis that the Hot Creek Hatchery springbrook inflows have lower biotic integrity than Mammoth Creek (Jellison et al. 2005a).

Jellison et al. (2007) conducted a re-analysis of BMI data across all years employing comparable data sets collected from 2000-2006. Biotic integrity (i.e., richness) was higher in Mammoth Creek compared to the springbrooks above the hatchery. EPT Index was higher at Mammoth Creek compared to CD springbrook ($p<0.05$) and probably AB springbrook ($p<0.1$). The percent of the benthic macroinvertebrate community comprised of tolerant organisms was much lower in Mammoth Creek than in Hot Creek, including the headsprings. Six of eleven commonly used metrics indicate statistically significant lower biotic integrity at springbrooks *above* the hatchery compared to Mammoth Creek and none indicated higher biotic integrity.

For Mammoth Creek, available benthic macroinvertebrate data and information is focused on the lowermost sections of the creek. The lowermost section of Mammoth Creek exhibits higher benthic macroinvertebrate biotic integrity than in Hot Creek below the Hot Creek Hatchery, above the Hot Creek Hatchery and even in the headsprings area which serves as inflow to the hatchery.

Jellison et al. (2007) note that only the sites located in the lowermost section of Mammoth Creek (by contrast to Hot Creek) exhibited index of biotic integrity (IBI) scores approaching those in reference streams in the Lahontan Region. However, Jellison et al. (2007) further note that this 12-metric IBI was developed to discriminate between impaired and reference streams where impairment was due to land development and/or grazing, and that the 12-metric IBI is simply another way to summarize and visualize the Hot Creek bioassessment data.

The lowermost section of Mammoth Creek would be most subject to the cumulative influences of contaminant inputs, nutrient loading, livestock grazing effects and associated sediment deposition, due to the downstream location and low-gradient nature of this section of the creek. The lowermost section of Mammoth Creek could be expected to exhibit the lowest benthic macroinvertebrate biotic integrity of the entire creek. Therefore, it is reasonable to assume that the sections of Mammoth Creek located upstream of the lowermost section would exhibit higher indices of benthic macroinvertebrate biotic integrity, and that Mammoth Creek benthic macroinvertebrates are in good condition.

6.7 POPULATION TEMPORAL TRENDS/FLOW CONSIDERATIONS

Of all of the various indices of abundance examined for the 17 years of fish survey data, YOY brown trout density is the most reliable indicator of the annual status of trout populations in Mammoth Creek because it is not directly influenced by the planting of hatchery fish, or by recreational angling.

As previously presented, what appears to be a slight trend of declining YOY brown trout abundance over the 17 years of fish survey data is not significant. Moreover, a slight but non-significant decreasing temporal trend in the annual average YOY brown trout densities for the entire (all reaches) Mammoth Creek study area also is evident in recent years (1999-2008). Recent years can be characterized as a relatively "wet" hydrologic period. In fact, over the 17 years included in the analysis, three of the five highest peak spring/early summer runoff flows (expressed as OMR High Flow) have occurred during the last six years, although 2007 was a dry year with the second lowest peak spring/early summer runoff flows in the 17-year study period (OMR High Flow = 36.7 cfs).

As previously discussed, over the 17 years of fish community surveys, brown trout populations have exhibited sporadic years of reduced abundance. MCWD and USFS (2000) attributes the episodic occurrences of low brown trout abundance to the influence of high runoff years that result in low population densities the following autumn. In the 1999 Fish Community Survey Report, Dr. Thomas Jenkins came to a similar conclusion, stating …

> *"Brown and rainbow trout populations are undergoing natural variations in population density, almost certainly in synchrony with other snow-melt dominated Easter Sierra streams. If minimum flows are not decreased beyond what has occurred in census years (e.g., to the point of exposing spawning gravels), and if the stream is not physically altered, we expect that the future trajectory of Mammoth Creek trout populations will depend primarily on the negative relationship between high stream flows and survival of juvenile trout."*

The analyses of the 17 years of Mammoth Creek fish survey data support these previous conclusions. Evaluation of the data demonstrates that YOY brown trout density is significantly associated with flow during the summer/autumn low-flow period in Mammoth Creek. In fact, the statistically significant trend in the data suggest that annual average YOY brown trout density is <u>negatively</u> associated with flow during the summer/autumn low-flow period (i.e., higher YOY brown trout density is associated with lower flow). This relationship may actually reflect the dominant influence of antecedent spring/early summer peak runoff flows on the establishment of brown trout initial year-class strength in Mammoth Creek. A highly significant, although moderately weak, negative relationship is evident between annual average YOY brown trout density and spring/early summer peak runoff flows (i.e., the higher the peak runoff flow, the lower the YOY brown trout density the following autumn).

The relationships between annual average YOY brown trout density and flow during the summer/autumn low-flow period should not be interpreted to mean that flows during summer and autumn are not important for juvenile rearing trout, or that flow-related habitat availability does not provide the opportunity for the establishment of relatively abundant initial year-classes of trout in Mammoth Creek. Rather, the available data from 1988-2008 most probably reflect the negative influence of spring/early summer peak runoff flows on the number of YOY brown trout present each year to utilize available summer/autumn rearing habitat in Mammoth Creek.

Finally, as previously presented, results indicate that due to the relatively high densities of YOY brown trout in Reach B, combined with the weak to moderate and significant decreasing linear trend in recent YOY brown trout density in Reach B, the overall slight declining linear trend in YOY brown trout density in Mammoth Creek during recent years (1999-2008) is most strongly influenced by Reach B. Also, a weak to moderate, and highly significant negative relationship is evident between annual average YOY brown trout density for the entire creek and spring/early summer peak runoff flows (i.e., the higher the peak runoff flow, the lower the YOY brown trout density the following autumn). However, further examination of the data reveals that annual average YOY brown trout density in Reach B (individually) is not significantly associated (r^2 = 0.11, P = 0.19) with spring/early summer peak runoff flow (expressed as OMR High Flow), whereas relatively weak (r^2 = 0.20, 0.29 and 0.26) and often significant (P = 0.07, 0.03, 0.04) negative relationships were found for reaches C, D and E, respectively. This conflicting trend in Reach B, relative to the entire Mammoth Creek, suggests that some other factor or factors contribute, at least partially, to the moderately strong and significant declining linear trend in YOY brown trout density in Reach B during recent years. Potential contributing factors are uncertain, although it is noted that Reach B passes through the Town of Mammoth Lakes, where much of the local area development has occurred during recent years. A discussion of the development and activities that have occurred over the past decade within and along Reach B of Mammoth Creek is presented in **Attachment B**.

6.8 CONCLUSIONS – CALIFORNIA FISH AND GAME CODE SECTIONS 5937 AND 5946

As previously discussed, CDFG's interpretation of maintenance of fish populations in good condition below a dam focuses on the ecological health of a stream, and identifies several components that contribute to ecological health, including fish population attributes and various stream habitat characteristics. The results of the analysis of 17 years of fish monitoring data in Mammoth Creek and available macroinvertebrate data indicate the following:

- Rainbow and brown trout annually persist in Mammoth Creek, and brown trout abundance is comparable to abundance estimates from 25 to 30 years ago in nearby creeks, as well as within Mammoth Creek itself
- The brown trout population in Mammoth Creek is resilient and has the ability to recover from episodic occurrences of reduced population numbers
- Mammoth Creek supports a self-sustaining population of brown trout comprised of multiple size/age classes, including adult-sized fish
- Resident trout, particularly brown trout, in Mammoth Creek are in good physical condition
- Habitat conditions in Mammoth Creek include sufficient cover, water quality, and habitat necessary for reproduction to maintain trout populations in good condition
- Successful reproduction of trout in Mammoth Creek occurs each year

- Available benthic macroinvertebrate community information suggests: (1) the aquatic invertebrate community from 1992 to 1994 in Mammoth Creek was relatively healthy; (2) sampling from 2000 through 2004 indicated that six of twelve metrics strongly support the hypothesis that Mammoth Creek has higher biotic integrity than even the Hot Creek Hatchery springbrook inflows; (3) updated analyses of 2000-2006 data demonstrated that biotic integrity (i.e., richness) was higher in Mammoth Creek compared to the springbrooks above the Hot Creek Hatchery.

  Available benthic macroinvertebrate data and information is focused on the lowermost sections of Mammoth Creek, which could be expected to exhibit the lowest benthic macroinvertebrate biotic integrity of the entire creek due to cumulative influences of contaminant inputs, nutrient loading, livestock grazing effects and associated sediment deposition. Therefore, it is reasonable to assume that the sections of Mammoth Creek located upstream of the lowermost section would exhibit higher indices of benthic macroinvertebrate biotic integrity, and that Mammoth Creek benthic macroinvertebrates are in good condition.

- YOY brown trout density, the most reliable indicator of the annual status of trout populations in Mammoth Creek, is significantly (albeit weakly to moderately) negatively associated with one expression of low flow during the summer/autumn low flow period. The relationship indicates that YOY brown trout densities decrease with increased flow during the summer/autumn low flow period. However, this relationship may actually reflect the dominant influence of antecedent spring/early summer peak runoff flows on the establishment of brown trout initial year-class strength

- For Mammoth Creek overall, YOY brown trout density is weak to moderately (but significantly) negatively associated with spring/early summer peak runoff flows (i.e., high peak runoff flows result in low YOY brown trout densities)

- The lack of a relationship between YOY brown trout densities in Reach B (individually) and flows suggests that other factors contribute, at least partially, to years of relatively low YOY brown trout densities in Reach B, the reach that passes through the Town of Mammoth Lakes

In conclusion, consideration of all of the above fish population attributes and stream characteristics indicates that the trout population in Mammoth Creek is in good condition.

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