Coho and Steelhead Restoration Project

Point Reyes National Seashore
Golden Gate National Recreation Area
Muir Woods National Monument

Annual Coho Salmon Spawner Survey Report 1997-98

National Park Service
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ABSTRACT

The Point Reyes National Seashore / Golden Gate National Recreation Area Coho and Steelhead Restoration Project conducted spawner surveys for coho salmon between November 1997 and January 1998 in the Olema, Redwood, and Lagunitas Creek watersheds. The surveys were the most comprehensive to date. National Park Service biologists and trained volunteers counted live fish, carcasses, and redds repeatedly in 13.4 km of the mainstem and seven tributaries of Olema Creek, 7.7 km of the mainstem and two tributaries of Redwood Creek, 1.5 km of Cheda Creek, and 3.2 km of Devil's Gulch. We summarized data collected by the Marin Municipal Water District and used information from all available sources to describe historic adult salmon abundance in each watershed. Peak Live Plus Cumulative Dead (PLD) and Area Under the Curve (AUC) methods were used to calculate indices of abundance for comparison to historical data. We did not attempt to test the assumptions of either method and were not able to assess the accuracy of the estimates. Little historical information was available for each stream. PLD index values for 1997-98 in the mainstems of Olema, Lagunitas, Devil's Gulch, Cheda, and San Geronimo Creeks were 88, 46, 27, 1, and 64 respectively. Spawners in the Lagunitas Creek watershed may have been less than 50% as abundant in 1997-98 as 1996-97. There appears to have been a precipitous decline in the number of spawners in Devil's Gulch over the past 50 years. The PLD index values for Redwood Creek were similar in 1997-98 (58), 1996-97 (57), and 1994-95 (58). AUC estimates showed the same trends as PLD index values for Redwood Creek. Carcass and redd counts were not reliable indices of abundance.

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INTRODUCTION

The National Park Service (NPS) is implementing a long term watershed restoration project in response to the Federal Endangered Species Act listing of coho salmon *(Oncorhynchus kisutch)* and steelhead trout *(O. mykiss)* along the central California coast. The coho and steelhead restoration project (CSRP) is a five year cooperative effort between Point Reyes National Seashore, Golden Gate National Recreation Area, and Muir Woods National Monument in western Marin County. The CSRP is evaluating fish population status, stream habitat, implementing restoration projects, and developing monitoring plans for the Redwood Creek, Pine Gulch, Olema Creek, and Lagunitas Creek watersheds.

During the fall and winter of 1997-98, the CSRP conducted spawner surveys in portions of the Lagunitas, Olema, and Redwood Creek watersheds. NPS staff and volunteers counted redds, live fish, and carcasses in an attempt to better understand trends in adult coho salmon abundance and distribution. Although both steelhead and coho are present in the three watersheds, we focused on coho because their life history characteristics are more amenable to accurate data collection. The objectives of surveys were to: (1) develop an index and/or total escapement estimate for adult coho salmon in the project streams for the analysis of long-term population trends; (2) determine the distribution of spawning coho salmon in the project streams; (3) determine population characteristics of coho adults including fish length, redd size, age, and sex; and (4) contribute tissue samples to a University of California Bodega Marine Laboratory project that is investigating the genetic diversity of coho salmon throughout California.

The 1997-98 surveys were a more comprehensive extension of earlier efforts. NPS staff began recording casual fish observations on Redwood Creek in 1944. In 1994, NPS biologists initiated more detailed surveys of Redwood Creek and assisted citizen groups with surveys on Olema Creek. The abundance of spawning coho in Devil's Gulch, a Lagunitas Creek tributary, was observed casually by California Department of Fish and Game personnel between 1948 and 1977 (A. Giddings and E. Gerstung pers. comm.). Systematic surveys of Devil's Gulch were conducted by consultants for the Marin Municipal Water District from 1983 to 1984 and from 1996 to 1997 (Bratovich and Kelley 1998; Trihey and Associates 1996, 1997). The sampling locations and timing of 1997-98 surveys will be duplicated in 1998-99 to develop an improved baseline for the assessment of long-term trends.

SURVEY AREA

Redwood Creek

Since 1994, the NFS has conducted annual surveys along a 6.7 km section of the mainstem of Redwood Creek between a point 140 m below the Pacific Way Bridge and a large debris jam 500 m above Bridge 4 in Muir Woods (Figure 1). The section encompassed most of the stream length used by coho salmon. To facilitate sampling, the section was divided into three reaches;

1) Pacific Way Bridge to the Kent Creek confluence in Mt. Tamalpais State Park (2.7 km),

2) Kent Creek confluence to Bridge 1 in Muir Woods (2.4 km) and,

3) Bridge 1 to 500 m above Bridge 4(1.6 km).

Portions of Fern and Kent Creeks, the two largest Redwood Creek tributaries, were also sampled in 1997-98 (Figure 1). The reach on Kent Creek extended from the confluence with Redwood Creek to a water fall, approximately 1 km upstream, that is impassable to migrating adults. The Fern Creek section has been surveyed since 1994 and extended between the Redwood Creek confluence and a series of steep cascades 1 km upstream. The debris jam that serves as the upstream limit of surveys on Redwood Creek and the high gradient cascade on Fern Creek are not impassable barriers for steelhead. However, neither coho salmon adults nor juveniles have been observed above these points and they are assumed to be coho barriers.

Olema Creek

A large section of the mainstem of Olema Creek, 17.6 km, has been surveyed by NPS staff and volunteers since 1993. The section was divided into 7 survey reaches to facilitate sampling (Figure 2). The reaches extend from:

1) one kilometer above the confluence with Lagunitas Creek to the Bear Valley
   Road Bridge in the town of Olema (3.0 km);

2) The Bear Valley Bridge to the confluence with Truttman Creek (3.2 km);

3) Truttman Creek to the horse trail crossing at the Stewart Ranch (2.6 km). Note; the storms of 1997-98 washed out the trail crossing;

4) Stewart Ranch to the first Hwy. 1 bridge at Five Brooks (1.3 km);

5) Five Brooks to the abandoned Lime Kilns (2.8 km);

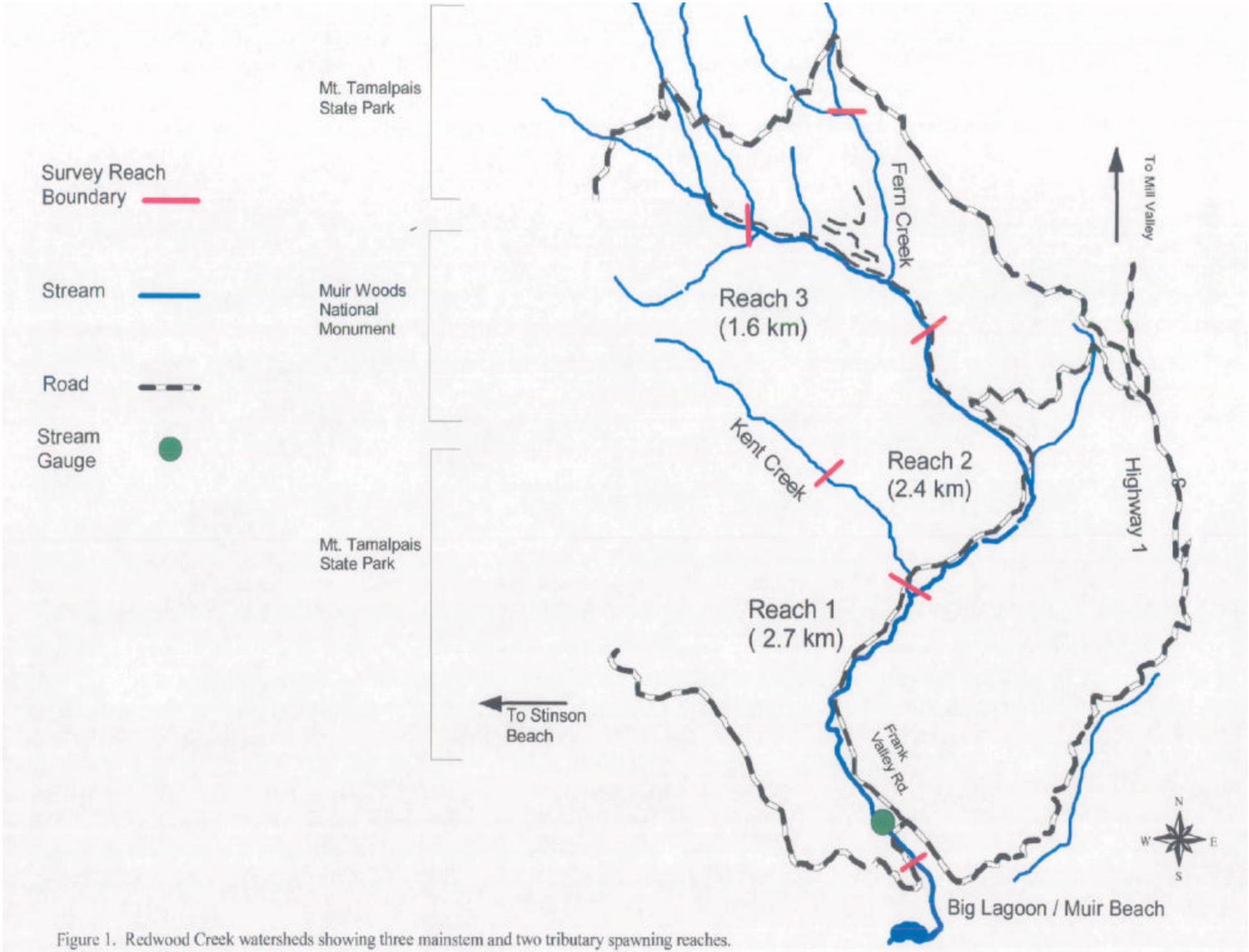


Figure 1. Redwood Creek watersheds showing three mainstem and two tributary spawning reaches.

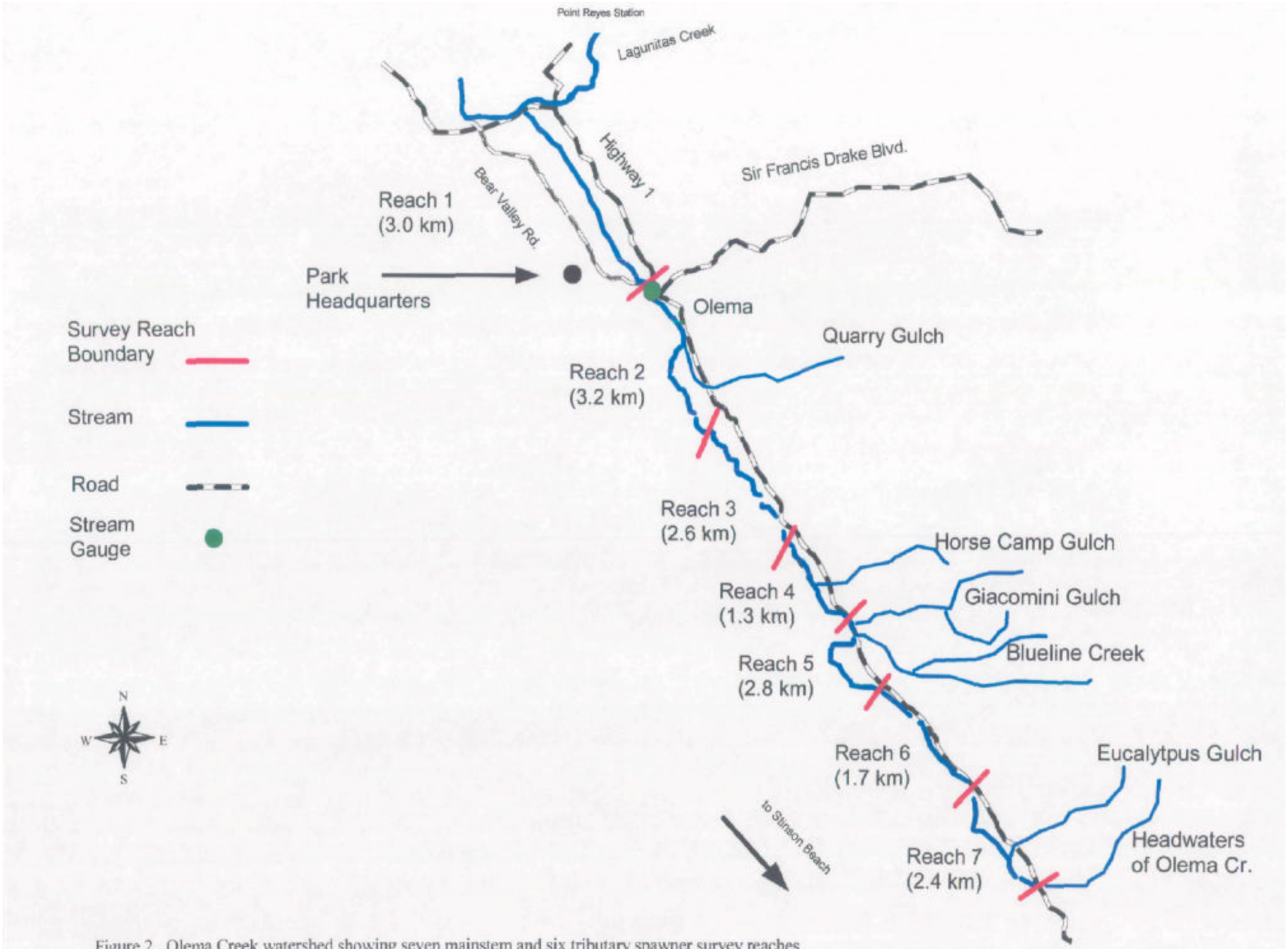


Figure 2. Olema Creek watershed showing seven mainstem and six tributary spawner survey reaches.

6) The Lime Kilns to the abandoned Randall ranch house (1.7 km);

7) The Randall House to the Hwy. 1 culvert at milepost 19.94 (2.4 km);

In addition to the mainstem of Olema Creek, surveys were conducted on six tributaries (Figure 2). Most tributary surveys were intended only to establish presence or absence of spawning coho and reach lengths varied widely. The six streams, many of them previously unnamed on U.S. Geological Survey (USGS) 7.5 minute maps, are:

1) Quarry Gulch located close to the Olema Cemetary 4.1 km above the mouth of Olema Creek at Hwy. 1 milepost 25.35.

2) Horse Camp Gulch located 9.6 km above the mouth of Olema Creek at Hwy. 1 milepost 23.26.

3) Giacomini Gulch located 10.8 km above the mouth of Olema Creek at Hwy. 1 milepost 22.78.

4) Blueline Creek located 10.9 km above the mouth of Olema Creek at Hwy. 1 milepost 22.67.

5) Eucalyptus Gulch located 16.6 km above the mouth of Olema Creek at Hwy. 1 milepost 20.33.

6) The Headwaters of Olema Creek (considered a tributary for the purposes of the survey due to the its physical characteristics) beginning at Hwy. 1 milepost 19.94.

Devil's Gulch

A 2 km index reach on Devil's Gulch, a Lagunitas Creek tributary, was surveyed by the Marin Municipal Water District in 1982-84 and 1995-97 (Trihey and Associates 1997). The NFS began sampling an extended reach during the 1996-97 season. The currently surveyed reach extends from the confluence with Lagunitas Creek in Samuel P. Taylor State Park to a steep cascade 3.2 km upstream (Figure 3). The cascade begins less than 50 m above a large culvert under the fire road that parallels the stream. Coho adults and juveniles have not been observed above the cascade and it is assumed to be a coho barrier. Steelhead juveniles, however, have been observed above the cascade.

Cheda Creek

Cheda Creek, a Lagunitas Creek tributary, was surveyed in 1996-97 and 1997-98 by the NFS to detect the presence or absence of coho. A consistent index survey reach was not established.

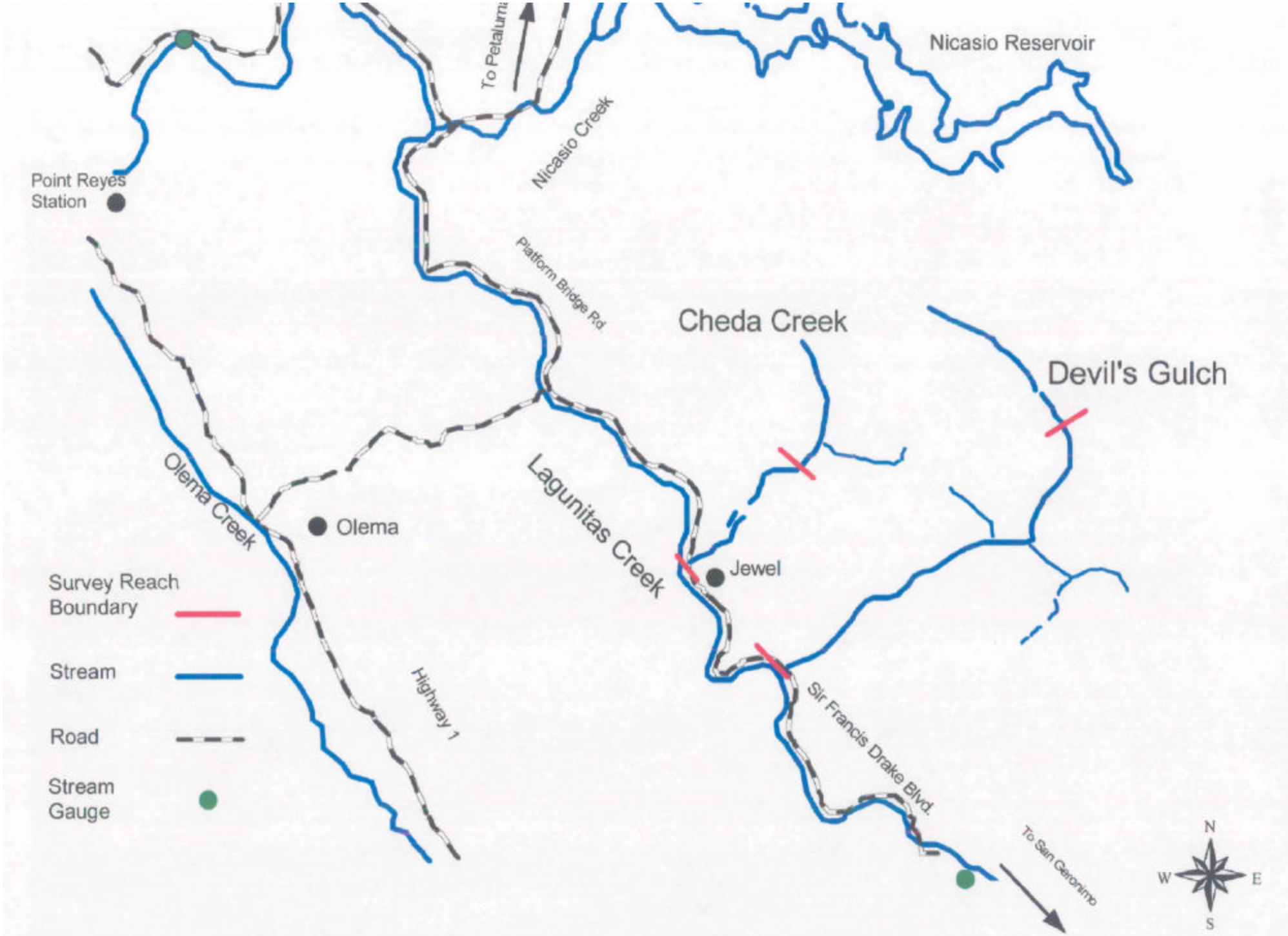


Figure 3. Lower Lagunitas Creek watershed showing Devil's Gulch and Cheda Creek spawner survey reaches.

METHODS

Visual Surveys

The methodology adopted by the CSRP has been used to estimate coho escapement in small streams throughout the Pacific Northwest (Johnston et al. 1987; Irvine et al. 1992; Anderson and McGuire 1994; Downie and Peterson (undated)). Live fish, carcasses, and redds were observed by weekly foot surveys conducted during the fall and winter. Teams of two observers walked upstream in the channel and along the banks of predetermined survey reaches. The sex and length of live fish was estimated. The fork lengths of carcasses were measured, tissue samples were collected, and marks were applied to prevent double counting in subsequent surveys. The length and width of redds were measured and locations were marked with plastic survey flagging. The locations of all live fish, carcasses, and redds were recorded in reference to permanent monument tags affixed to trees or metal stakes every 100m along each stream. A more detailed description of the survey procedure and monument tags can be found in the CSRP document titled *Spawner Survey Protocol 1998* (Appendix A).

Environmental conditions were also monitored throughout the spawning season. Before beginning each survey, observers noted weather conditions and measured water clarity using a graduated rod. Rainfall data was logged continuously from tipping bucket gages at two locations along Olema Creek (Bear Valley and Hagmeirs Ranch) and at one site along Redwood Creek. Stream stage was monitored continuously by pressure transducers at the Bear Valley Bridge on Olema Creek and Highway 1 Bridge at Redwood Creek (Figure 2). Stage was monitored continuously on Lagunitas Creek by two USGS stations at Samuel P. Taylor State Park and Point Reyes Station. Rating curves were developed from frequent depth and velocity measurements at both sites. Flows were also gauged periodically in several Olema Creek tributaries and Devil's Gulch.

Analysis

The analysis of spawner survey data is complicated by annual variability in environmental conditions and run characteristics. Accurate abundance estimates are difficult to generate without counting weirs or other intensive sampling techniques (Irvine et al. 1992). The CSRP is, nonetheless, interested in developing precise indices of abundance. Two techniques, Peak Live Plus Cumulative Dead (PLD) and Area Under the Curve (AUC) were used to compute index values (Beidler and Nickelson 1980; Johnston et al. 1987). In addition to calculating the indices, we summarized the live fish, redd, carcass, and environmental data for each stream.

The PLD and AUC estimates provide different types of information. While the PLD index produces a minimum instantaneous estimate, the AUC method is used to calculate a total population estimate. The PL index is computed as the name suggests. The peak number of live fish observed during a single day of the spawning season is added to the cumulative number of unmarked carcasses observed prior to that date. The AUC estimate is calculated using the total number of live fish observed during each survey and the average life offish on the spawning grounds (residence time). Calculating the area under the curve created by plotting the live fish

observations for each survey, produces a quantity termed total fish-days. The area under the escapement curve was given by:

$$AUC = 0.5 \{ \sum (t_i - t_{i-1}) (p_i + p_{i-1}) \}$$

where t_i is the number of days since the first fish entered the survey area and p_i is the total number offish observed on the i^{th} day (Irvine et al. 1992). Dividing the total number offish days by the residence time, gives the population estimate. Because we did not estimate residence time, separate AUC estimates were computed using the range of values, 8 to 17 days, presented in the literature (Moring and Lantz 1975; Johnston et al. 1987; Irvine et al. 1992). Data collection typically stops after repeated surveys no longer indicate the presence of live coho. High flows prevented us from conducting surveys during the tail portion of the run in 1997-98. If fish were observed during the last survey of the season, the last date used for calculating the AUC estimate was arbitrarily set at 10 days after the final survey date.

RESULTS

Live Fish, Carcass, and Redd Observations

Olema Creek Watershed

Live Fish

Between November 13, 1997 and January 8, 1998, 241 live adult coho were observed in the mainstem of Olema Creek (Table 1). Because the surveys were conducted frequently, many individual fish were counted more than once. Therefore, the total number of live fish observations is not an accurate estimator of the total spawning escapement. The first three fish were observed on November 18 (Figure 4). The peak of the run, 81 fish, occurred on December 12 and 17 fish were observed on January 8, the final survey date. The total density of spawners during the peak of the run was 5 fish per km. Most live fish were observed in reaches three, five, and six (Figure 5). There were a total of 71 live fish sightings in reach six. During the peak of the run, reach six had the highest density of spawners (19 fish per km). The sex ratio from live fish observations was 45% male, 41% female, and 14% unknown (Figure 6).

A total of 32 live coho were sighted in seven Olema Creek tributaries between December 1 and January 22 (Table 2). The majority of the sightings, 71%, occurred on Blueline Creek. The peak of the run on Blueline Creek (12 fish) and Giacomini Gulch (3 fish) occurred on December 10. During the peak of the run on Blueline Creek, nine of the twelve fish were observed in the 200 m of stream below the Highway 1 culvert. Five fish were seen in Quarry Gulch on January 8 and one fish was found in Randall Creek on December 13. Coho were not observed in Horse Camp Gulch, Eucalyptus Gulch, and the headwaters of Olema Creek.

Table 1 . The number of live coho salmon, carcasses, and redds observed during each spawner survey in the mainstem of Olema Creek during 1997-98. Live fish observations do not represent the total number of spawning adults.

Date	Total Distance Surveyed (km)	Reach	Live Fish	Carcasses	New Redds
Nov 13 ...	4.8	1-2	0	0	0
Nov 18	4.5	2-4	3	0	1
Nov 24	8.7	1-4	2	0	3
Dec 2	8.7	1-4	38	1	17
Dec 12	13.4	1-7	81	6	39
Dec 20	11.8	2-7	70	9	28
Dec 29	11.8	2-7	30	15	28
Jan 8	6.7	3-6	17	9	10
Total			241	40	126

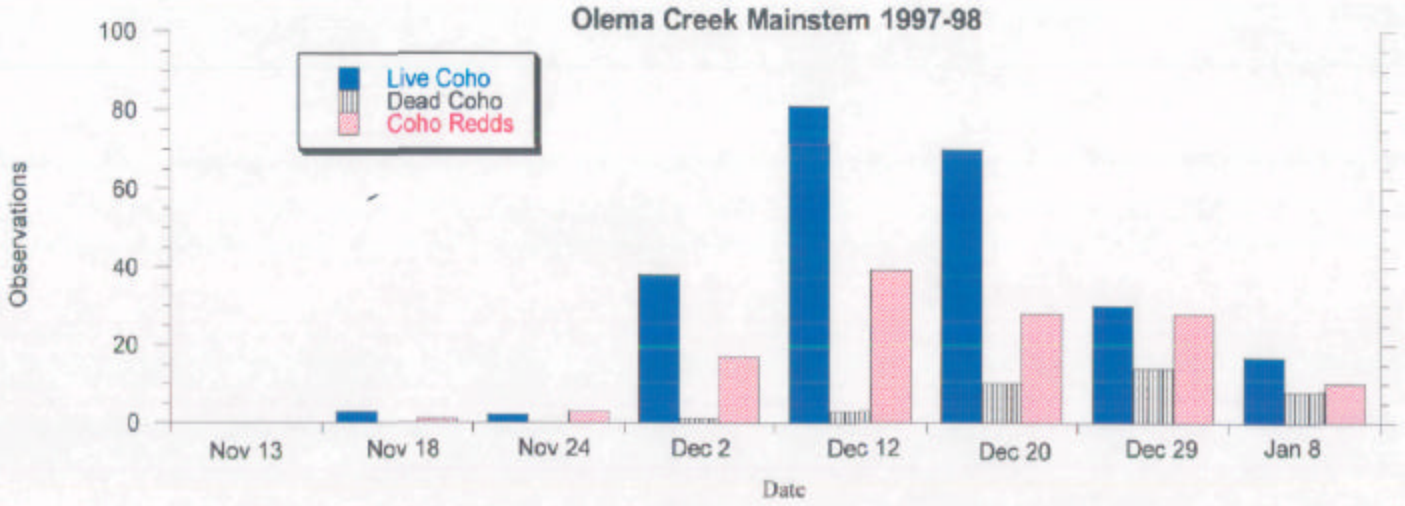


Figure 4. Total live fish, carcass, and redd observations for coho salmon in the mainstem of Olema Creek during 1997-98. Total live fish observations do not represent the true number of spawning adults.

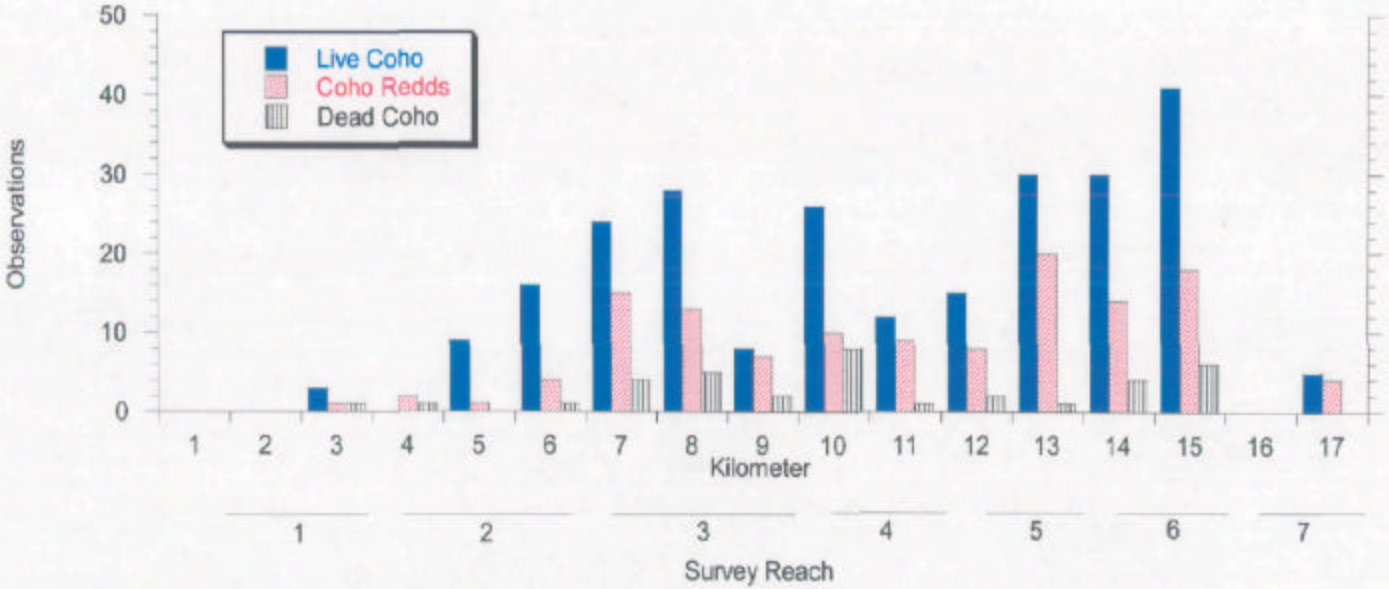


Figure 5. Total live fish, carcass, and redd observations for coho salmon in each kilometer of mainstem Olema Creek during 1997-98. Live fish observations do not represent the true number of spawning adults.

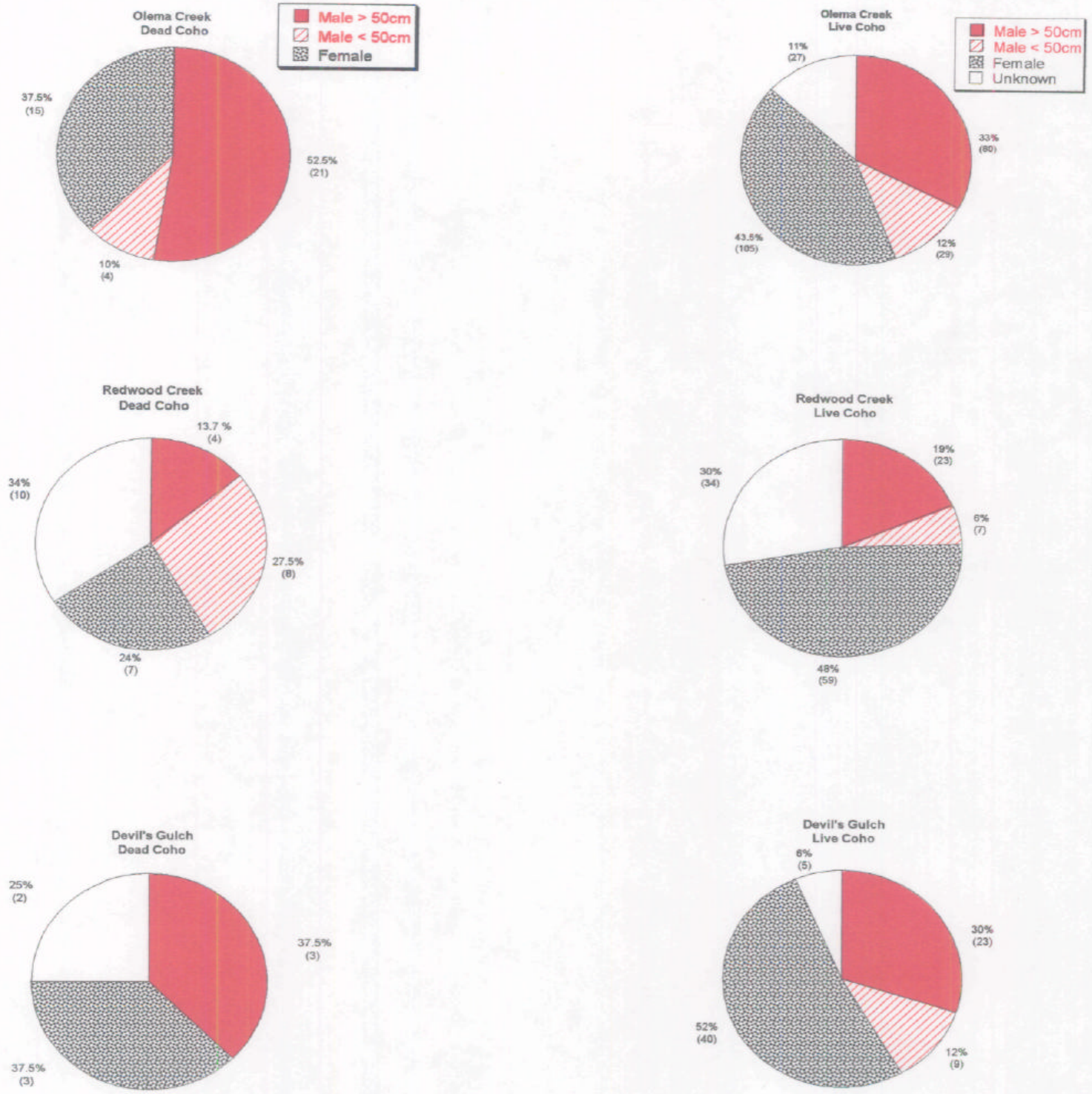


Figure 6. Sex ratios from carcass counts and live fish observations on Olema Creek, Redwood Creek, and Devil's Gulch during 1997-98. Sample sizes are in parenthesis.

Table 2. The number of live coho salmon, carcasses, and redds observed during spawner surveys in six tributaries and the headwaters of Olema Creek during 1997-98. Live fish observations do not represent the total number of spawning adults. Steelhead observations in Blueline Creek are indicated by an asterisk and were excluded from the totals.

Stream	Date	Total Distance Surveyed (km)	Live fish	Carcasses	New Redds
Quarry Gulch	Dec 9	1.4	0	0	0
	Dec 13	1.4	0	0	0
	Jan 8	1.5	5	0	0
Horse Camp Gulch	Dec 13	0.4	0	0	0
	Jan 8	0.6	0	0	0
Giacomini Gulch	Dec 1	0.7	0	0	0
	Dec 10	0.7	3	0	2
	Dec 16	0.7	0	0	0
Blueline Creek	Dec 1	1.4	8	0	1
	Dec 10	1.4	12	0	3
	Dec 16	2.2	2	0	0
	Dec 30	2.2	0	0	2
	Jan 6	0.3	1	0	0
	Jan 22	1.2	2*	0	0
	Jan 28	0.2	2*	0	0
	Feb26	2.0	3*	0	2*
Randall Creek	Dec 13	0.4	1	1	0
Eucalyptus Gulch	Dec 19	0.2	0	0	0
Olema Creek	Dec 19	0.5	0	0	0
Headwaters	Jan 10	1.0	0	0	0
	Jan 22	0.5	0	0	0
Total			32	1	8

Carcasses

A total of 40 carcasses were found on the mainstem of Olema Creek during the 1997-98 season (Table 1). One carcass was recovered in Randall Creek. Tissue samples from 33 fish were sent to the Bodega Marine Laboratory for genetic analysis. Six marked carcasses were recaptured during subsequent surveys. Most carcasses were recovered during the December 20 and 29 surveys; one to two weeks after the peak number of live fish were observed (Figure 4). Most carcasses were found in reaches three, four, and six (Figure 5). The carcass sex ratio was 62.5 % male and 37.5 % female (Figure 6). Based on the distribution offish sizes, it appeared that jacks (precocious two year old males) composed 10 % of the recovered fish. Scales were collected from all individuals and we plan to use them to separate two and three year old males. The mean fork length of male and female carcasses was 61 cm (SD 9.6 cm) and 59 cm (SD 3.2 cm) respectively. The results of previous spawner surveys in the Olema Creek watershed suggested that jacks were typically less than 50 cm fork length. The mean length of males less than 50 cm fork length during the 1997-98 surveys was 45 cm (SD 4.6 cm).

Redds

A total of 126 redds were observed in the mainstem of Olema Creek (Table 1). Two redds were found in Giacomini Gulch and six redds were identified in Blueline Creek. Most mainstem redds were constructed after December 13. The total density of redds in the 13.4 km mainstem survey section was 9.4 redds per km. Reaches three, four, and six contained the greatest density of redds (Figure 5). Reach six had 19 redds per km and reaches three and four had 14 and 15 redds per km respectively. Only nine redds were found in reaches one and two. The mean surface area of all redds was 3.8 m^2 (SD 3.6). Observers made comments about features of the stream bed that could not be positively identified as redds. A total of 18 questionable redds were found. The mean surface area of 15 questionable redds was 5.8 m^2 (SD 6.4).

Redwood Creek Watershed

Live Fish

A total of 162 live adult coho were observed in the Redwood Creek watershed between November 25, 1997 and January 23, 1998. Most of the sightings, 151, were made in the mainstem of Redwood Creek (Table 3). Two fish were observed during the first survey in November, the peak of the run (53 fish) occurred on January 7, and six fish were seen during the last survey on January 23 (Figure 7). An initial pulse of fish (46 observations) on December 18 was close to the January 7 peak. The majority, 44% (67), of the live fish were observed in reach 3 (Figure 8). The total density of spawners during the peak of the run was 8 fish per km. The density of live fish during the peak of the run in

Table 3. The number of live adult coho salmon, carcasses, and redds observed in Redwood Creek and its two major tributaries, Kent and Fern Creeks during 1997-98. Live fish observations do not represent the true number of spawning adults. The total length of the three survey reaches on the mainstem of Redwood Creek is 6.7 km. The Kent and Fern Creek reaches are 1 km long.

Stream	Date	Total Distance Surveyed (km)	Live Fish	Carcasses	New Redds
Redwood	Nov 25	6.7	2	0	1
Kent		n.a.	n.a.	n.a.	n.a.
Fern		n.a.	n.a.	n.a.	n.a.
Redwood	Dec 3	6.7	10	2	3
Kent		n.a.	n.a.	n.a.	n.a.
Fern		n.a.	n.a.	n.a.	n.a.
Redwood	Dec 12	6.7	26	10	10
Kent		1	0	0	0
Fern		n.a.	n.a.	n.a.	n.a.
Redwood	Dec 18	6.7	46	1	36
Kent		n.a.	n.a.	n.a.	n.a.
Fern		1	0	0	0
Redwood	Dec 29	6.7	19	7	6
Kent		n.a.	n.a.	n.a.	n.a.
Fern		n.a.	n.a.	n.a.	n.a.
Redwood	Jan 7	6.7	42	3	20
Kent		1	2	0	0
Fern		1	9	0	5
Redwood	Jan 23	6.7	6	7	3
Kent		n.a.	n.a.	n.a.	n.a.
Fern		1	0	0	0
Total			162	30	84

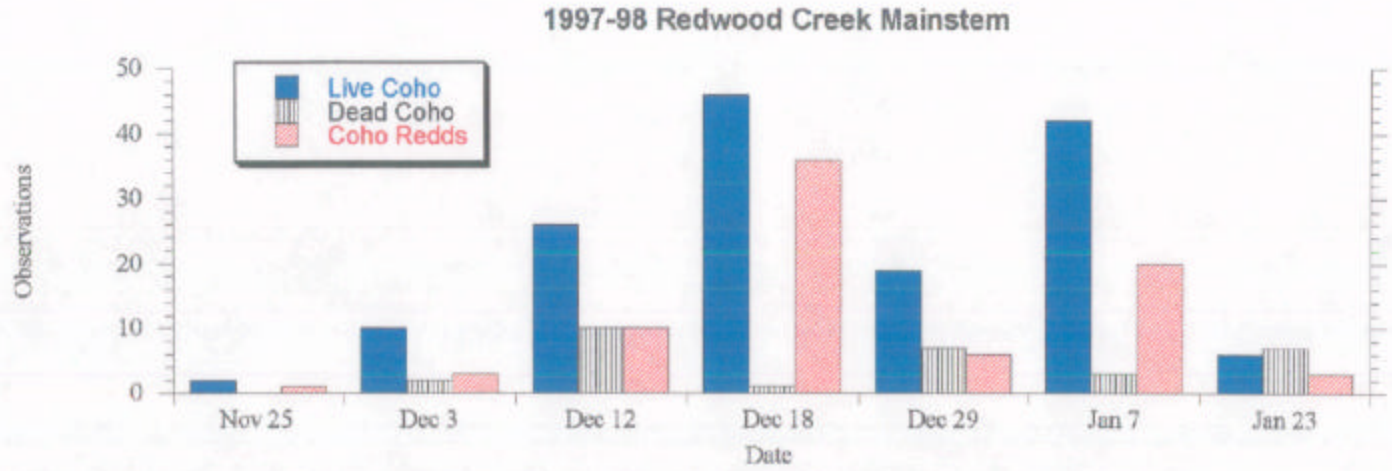


Figure 7. Total live fish, carcass, and redd observations for coho salmon in the mainstem of Redwood Creek during 1997-98. Live fish observations do not represent the true number of spawning adults.

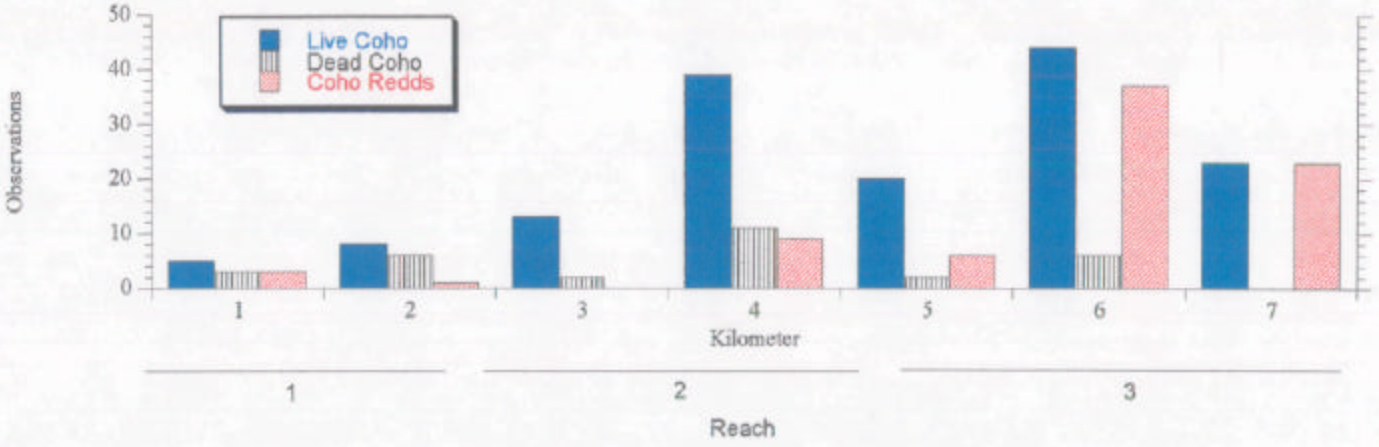


Figure 8. Total live fish, carcass, and redd observations for coho salmon in each kilometer and survey reach of mainstem Redwood Creek during 1997-98. Live fish observations do not represent the true number of spawners.

reaches one through three were 3, 2, and 18 spawners per km respectively. The sex ratio from live fish observations was 27% male, 52% female, and 21% unknown. Two fish were observed in Kent Creek and 9 fish were seen in Fern Creek on January 7.

Carcasses

A total of 30 carcasses were recovered in the mainstem of Redwood Creek during the 1997-98 season. No carcasses were found in Kent or Fern Creeks (Table 3). Tissue samples from sixteen individuals were sent to the Bodega Marine Laboratory for genetic analysis. No marked carcasses were recaptured. Ten carcasses were recovered on December 12; one week after ten live fish were counted (Figure 7). However, there were not any clear relationships between the number of carcasses and the two peaks of the run on December 18 and January 7. It is likely that high flows in January scattered carcasses and made them difficult to detect. Most carcasses were found in reaches two and three (Figure 8). The carcass sex ratio was 43 % male, 25 % female, and 32 % unknown. Based on the distribution offish sizes, it appeared that jacks composed 29 % of the recovered carcasses. The mean fork length of male and female carcasses was 46 cm (SD 2.3 cm) and 54.8 cm (SD 4 cm) respectively. The mean length of males less than 50 cm fork length was 39 cm (SD 1.3 cm).

Redds

A total of 79 redds were identified in the mainstem of Redwood Creek. (Table 3). Five redds were found in Fern Creek on January 7. No redds were found in Kent Creek. Most mainstem redds were found after December 18 (Figure 7). The total density of redds from the 6.7 km mainstem survey section was 12 per km. Reach three had the highest density of redds (37.5 / km) and reach one had the lowest (1.5 / km) (Figure 8). The mean surface area of redds was 2.7 m^2 (SD 2.2). Eleven questionable redds were identified. The mean surface area of questionable redds was 1.7 m^2 (SD 1.3).

Lagunitas Creek Watershed - Devil's Gulch and Cheda Creek

Live Fish

Between November 17, 1997 and January 23, 1998, 79 live adult coho were observed in Devil's Gulch (Table 4). During the same time period, one coho was seen in Cheda Creek (Table 5). One fish was observed during the first survey on Devil's Gulch, the peak of the run (26 fish) occurred on December 11, and no fish were found on the last survey date. The single fish on Cheda Creek was spotted on December 11. The density of spawners during peak on Devil's Gulch was 8 fish per km. The highest density offish during the peak occurred between 2 and 3 km above the confluence with Lagunitas Creek. The sex ratio for live fish in Devil's Gulch was 42% male (12% jacks), 52% female, and 6 % unknown (Figure 6).

Table 4. The number of live adult coho salmon, carcasses, and redds observed in Devil's Gulch during 1997-98. Live fish observations do not represent the true number of spawning adults.

Date	Total Distance Surveyed (km)	Live Fish	Carcasses	New Redds
Nov 17	3.2	1	0	0
Nov 25	3.2	4	1	2
Dec 3	3.2	12	0	10
Dec 11	3.2	26	2	11
Dec 17	3.2	18	3	6
Dec 31	3.2	1	0	5
Jan 6	3.2	17	2	12
Jan 23	3.2	0	1	0
Total		79	9	46

Table 5. The number of live adult coho salmon, carcasses, and redds observed in Cheda Creek during 1997-98. Live fish observations do not represent the true number of spawning adults.

Date	Total Distance Surveyed (km)	Live Fish	Carcasses	New Redds
Nov 17	2.1	0	0	0
Nov 25	2.1	0	0	0
Dec 11	1.0	1	0	0
Dec 31	1.5	0	0	0
Jan 23	1.5	0	0	0

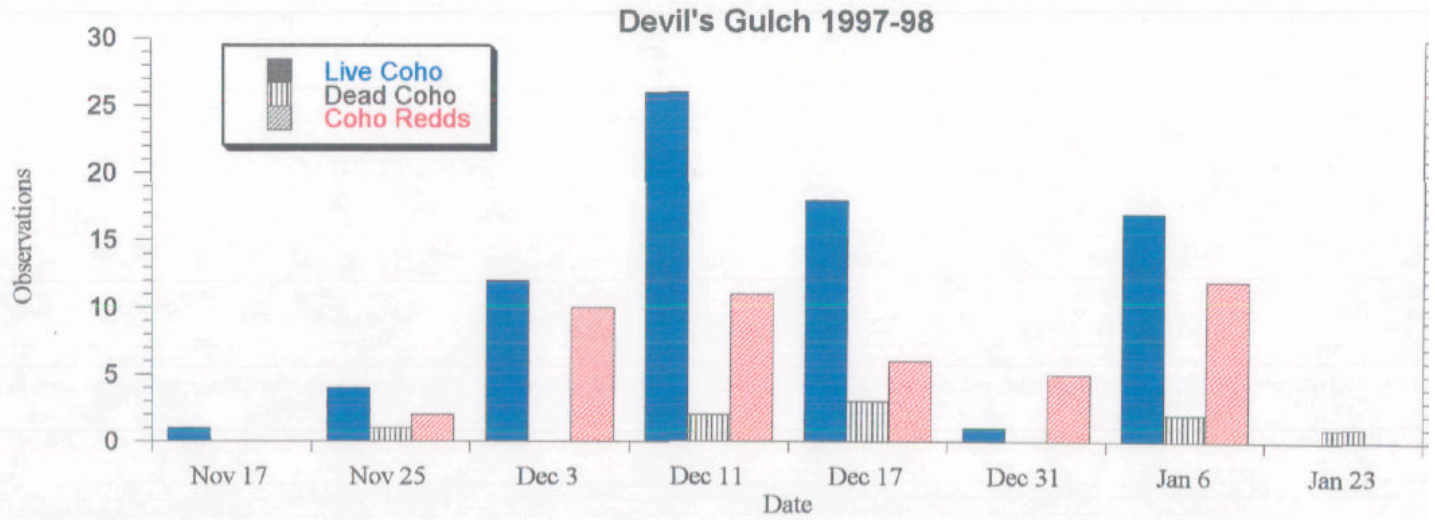


Figure 9. Total live fish, carcass, and redd observations for coho salmon in Devil's Gulch during 1997-98. Live observations do not represent the true number of adults.

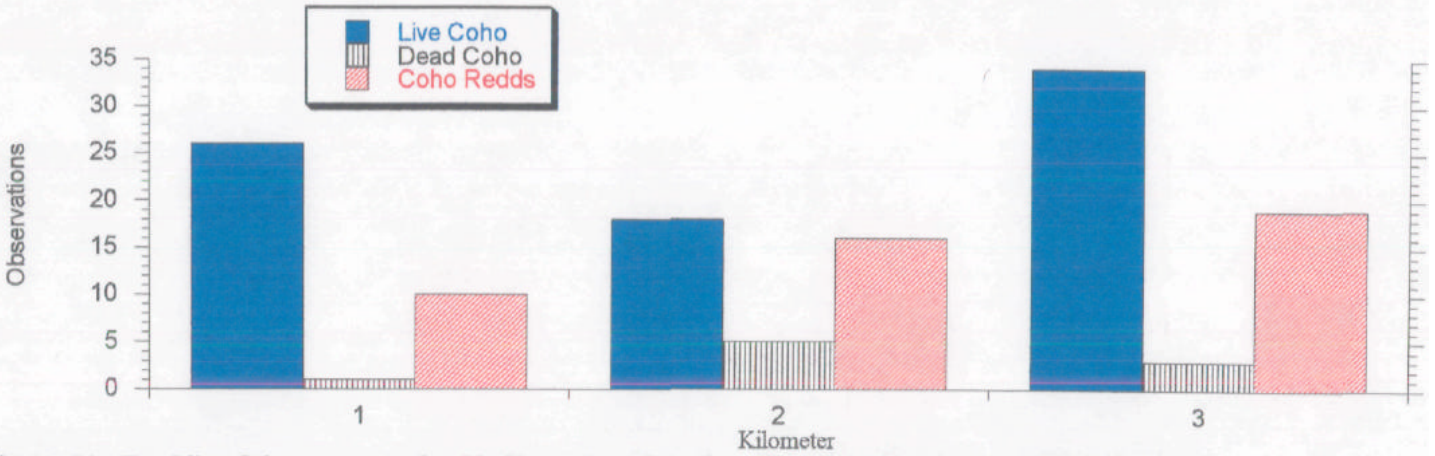


Figure 10. Total live fish, carcass, and redd observations for coho salmon in each kilometer of Devil's Gulch during 1997-98. Live fish observations do not represent the true number of adults.

Carcasses

Nine carcasses collected in Devil's Gulch (Table 4). No carcasses were recovered on Cheda Creek. Tissue samples from eight fish were sent to the Bodega Marine Laboratory for genetic analysis. No marked carcasses were recaptured. There were no apparent trends in the number of recovered carcasses and live fish observed (Figure 9). Most carcasses were found between 2 and 3 km upstream (Figure 10). The carcass sex ratio was 37.5 % male, 37.5 % female, and 25 % unknown (Figure 6). The mean fork length of male and female carcasses was 61.5 cm (SD 5 cm) and 60.7 cm (SD 6.7) respectively.

Redds

A total of 46 redds were identified in Devil's Gulch and none were found in Cheda Creek. Most redds were found after December 11 (Figure 9). The total density of redds in the 3.2 km section of Devil's Gulch was 14 per km. Although the distribution of redds was fairly even, most were found 2 to 3 km upstream (Figure 10). The mean surface area of redds was 3.3 m^2 (SD 2.0).

Survey Timing and Environmental Conditions

Olema Creek Watershed

Eight surveys were conducted in Olema Creek between November 13, 1997 and January 8, 1998. The mean interval between surveys was eight days. Mean daily flow during the surveys ranged between 0.12 m^3/s (4.4 cfs) on December 29 to 1.06 m^3/s (37.6 cfs) on January 8 (Table). Average water clarity at the time of surveys ranged between 20 and 83 cm. Water clarity was greater than 50 cm during six of the eight surveys. The onset of higher flows appeared to be related to live fish observations. The number of observations increased from 2 fish on November 24 to 38 fish on December 2. The mean daily flow for the week preceding each survey increased from 0.04 m^3/s (1.3 cfs) on November 13 to 2.45 m^3/s (86.4 cfs) on December 2 (Table 6).

The Olema Creek mainstem reaches were not consistently sampled during each survey. Only reaches two through four were sampled on each occasion. Reaches one through four were sampled between November 18 and December 2. Reach one was not sampled after December 12 because few fish were observed and habitat conditions in the lower portions of the stream did not appear to be conducive to spawning. Reaches two through seven were surveyed between December 12 and 29. The channel in reach seven is narrow, incised, and the banks are lined with dense riparian shrubs and woody debris. Wading upstream is hazardous during even low winter flows and observation from the bank is difficult. We attempted to survey the entire 4.1 km reach but less than 500m was sampled consistently.

Table 6. Daily average flow, 7 day average flow prior to each survey, average water clarity, and the number of live coho observed in 1997-98 on the mainstem of Olema Creek. Live coho observations are reported for all reaches that were surveyed on a particular date and for reaches 2 through 4. Only reaches 2 through 4 were consistently sampled during each survey.

Date	Daily Average Flow m^3/s (cfs)	7 Day Average Flow Prior to Survey m^3/s (cfs)	Average Water Clarity (cm)	Live Coho	
				Total Survey	Reach 2-4
Nov 13	0.23 (8.2)	0.04 (1.3)	20	0	0
Nov 18	0.26 (9.2)	0.22 (7.7)	20	3	3
Nov 24	0.37 (13)	0.55 (19.3)	53	2	2
Dec 2	1.04 (36.7)	2.45 (86.4)	56	38	30
Dec 12	0.53 (18.8)	1.43 (50.4)	70	81	36
Dec 20	0.43 (15.3)	0.87 (30.7)	72	70	31
Dec 29	0.12 (4.4)	0.18 (6.2)	83	30	15
Jan 8	1.06 (37.6)	1.33 (46.8)	50	17	7

Seven tributaries were surveyed between December and February. The timing of tributary surveys generally followed the mainstem surveys. Blueline Creek was sampled eight times. Sections of Quarry Gulch, Giacomini Gulch, and the Olema Creek headwaters were surveyed three times. Horse Camp Gulch was sampled twice and Randall Creek and Eucalyptus Gulch were surveyed once. Water clarity in Blueline Creek exceeded 50 cm during five of the eight surveys. Clarity was less than 50 cm in the other six streams. The length of survey sections in each tributary varied widely over the course of the season (Table 2). On six out of eight occasions, at least 1 km of Blueline Creek was surveyed.

Strong El Nino driven storms created acceptable survey conditions for only one day on Quarry Gulch, Horse Camp Gulch, and the mainstem of Olema Creek during January and February 1998. Blueline Creek was surveyed three times in January and once in February. The headwaters of Olema Creek were surveyed twice in January. Bankfull flow in Olema Creek, (approximately 14 m^3/s (500 cfs)) at the Bear Valley Bridge, was equaled or exceeded for two days in January and four days in February (Table 7). The peak discharge during January, 43 m^3/s (1525 cfs), was approximately three times bankfull. Total January precipitation, 45.7 cm (18 inches), was the fourth highest in 33 years of record at the Bear Valley gage. Mean daily flows increased from 0.84 m^3/s (28.5 cfs) in December to 4.78 m^3/s (168.7 cfs) in January and 10.55 m^3/s (372.6 cfs) in February (Table 7). The peak discharge, 2503 cfs, was the highest on record and February storms released a record 25 inches of rainfall (Appendix B).

Redwood Creek Watershed

Seven surveys were conducted on the mainstem of Redwood Creek between November 25, 1997 and January 23, 1998. The mean interval between surveys was 10 days. Mean daily flow during the surveys ranged between 0.14 m^3/s (5 cfs) on December 29 to 1.17 m^3/s (41.1 cfs) on January 23 (Table 8). Average water clarity at the time of surveys ranged between 60 and 138 cm. Water clarity was greater than 100 cm during five of the seven surveys. Anadromous fish access to Redwood Creek is controlled by the breaching of a sand bar at the mouth of the stream. Stream flows were not gauged until November 20. However, two storms between November 10 and 16 released 3 inches of rain and probably created flows that were capable of breaching the bar. The number of observations increased from 2 fish on November 25 to 10 fish on December 3. The mean daily flow for the week preceding each survey increased from 0.17 m^3/s (6.6 cfs) on November 25 to 0.60 m^3/s (21.1 cfs) on December 3 (Table 8). The three mainstem reaches (6.7 km) were sampled during every survey. The 1 km sections of Kent and Fern Creek were sampled periodically (Table 3).

We completed only two surveys in January because high flows in the middle of the month created difficult survey conditions. High flows and turbid water prevented us from conducting surveys during February. Bankfull flow, approximately 9.1 m^3/s (320 cfs), was equaled or exceeded for two days in January and two days in February (Table 7).

Table 7. Total rainfall, mean daily flow, maximum mean daily flow, and the number of days that flow exceeded the bankfull discharge between November 1997 and February 1998 in Olema Creek (OLM), Redwo od Creek (RDW), and Lagunitas Creek (LGN). Olema Creek rainfall data was collected at the Bear Valley Weather Station in Olema and Redwood Creek rainfall was collected at the NFS gauge near the Highway One Bridge. Lagunitas flow data was taken from the USGS gauge station at Samuel P. Taylor State Park. Discharge in Lagunitas Creek is partially regulated by releases from Peter's Dam.

Month	Total Rainfall cm (in)			Mean Daily Flow m^3/s (cfs)			Max Mean Daily Flow m^3/s (cfs)			Number Days Flow Exceeded Bankfull		
	OLM	RDW	LGN	OLM	RDW	LGN	OLM	RDW	LGN	OLM	RDW	LGN
November 1997	26.2 (10.3)	20.0 (7.9)	n.a.	0.69 (24.2)	0.56 (19.7)	1.22 (43)	5.88 (207.6)	2.13 (75.3)	7.22 (255)	0	0	0
December 1997	8.8 (3.5)	8.4 (3-3)	n.a.	0.81 (28.5)	0.42 (14.8)	1.25 (44.2)	2.65 (93.5)	1.29 (45.6)	4.70 (166)	0	0	0
January 1998	45.7 (18.0)	30.4 (12.0)	n.a.	4.78 (168.7)	3.34 (118.1)	8.67 (306)	18.77 (663)	14.57 (514.6)	25.88 (914)	2	2	0
February 1998	62.7 (24.7)	42.0 (16.5)	n.a.	10.55 (372.6)	4.61 (162.9)	22.54 (796)	37.9 (1340)	14.12 (498.6)	81.27 (2870)	4	2	4

Table 8. Daily average flow, 7 day average flow prior to each survey, average water clarity, and the number of live coho observed in 1997-98 on the mainstem of Redwood Creek.

Date	Daily Average Flow m^3/s (cfs)	7 Day Average Flow Prior to Survey m^3/s (cfs)	Average Water Clarity (cm)	Number of Live Coho
Nov 25	0.18 (6.3)	0.17 (6.6)	102	2
Dec 3	0.33 (11.7)	0.60 (21.1)	113	10
Dec 12	0.41 (14.8)	0.75 (26.6)	128	26
Dec 18	0.43 (15.1)	0.49 (17.4)	115	46
Dec 29	0.14 (5.0)	0.18 (6.2)	138	19
Jan 7	0.65 (22.9)	0.53 (18.7)	72	42
Jan 23	1.17 (41.4)	4.02 (142.0)	60	6

The peak January flow, 21.7 m^3/s (766) cfs, was twice bankfull. The January storms released a total of 30.4 cm (12 in) of rain and mean daily flow for the month was 3.34 m^3/s (118 cfs) (Table 7). As in the Olema Creek watershed, February storms produced near record rainfall and stream flow. Mean daily flow for February was 4.1 m^3/s (163 cfs) and total rainfall was 42 cm (16.5) inches (Appendix B).

Lagunitas Creek Watershed - Devil's Gulch and Cheda Creek

Stream flow and rainfall were not gauged continuously on Devil's Gulch and Cheda Creek. However, both streams likely respond to the same patterns in precipitation as Olema Creek and flow data was available from the mainstem of Lagunitas Creek. Although flow in the mainstem of Lagunitas Creek is regulated above the confluence of both streams by releases from Peter's Dam, flows from San Geronimo Creek and numerous small tributaries are unregulated. Mean daily flow values from the Samuel P. Taylor gage were used to indicate relative flows in Devil's Gulch and Cheda Creek.

Devil's Gulch was surveyed eight times and Cheda Creek was surveyed five times between November 17, 1997 and January 23, 1998. The mean interval between surveys was 10 days. Mean daily flow in Lagunitas Creek during the surveys ranged between 0.76 m^3/s (27 cfs) on December 31 to 4.93 m^3/s (174 cfs) on January 23 (Table 9). Average water clarity in Devil's Gulch ranged between 20 and 100 cm. Water clarity was greater than 50 cm during six of the eight surveys. The peak number of live fish on Devil's Gulch was observed after the seven day average flow in Lagunitas increased from 1.49 m^3/s (52.7 cfs) to 2.15 m^3/s (76 cfs) (Table 9). Increased flows in early January induced a second peak in the number of spawners. One live fish was observed during the December 31 survey and mean daily flow during the preceding week averaged 0.71 m^3/s (25 cfs). Seventeen fish were observed six days later after the weekly average flow increased to 2.23 m^3/s (78.6 cfs).

As in the Olema and Redwood Creek watersheds, strong storms in January and February afforded few opportunities to conduct surveys. During January, Devil's Gulch was surveyed twice and Cheda Creek was sampled once. Mean daily flow in Lagunitas Creek increased from 2.23 m^3/s (79 cfs) on January 6 to 14.1 m^3/s (497 cfs) on the January 23 (Table 7). The mean daily flow for the month was 8.67 m^3/s (306 cfs). Mean daily flow in February was 22.54 m^3/s (796 cfs) at the Samuel P. Taylor gauge and 52 m^3/s (1840 cfs) at the Point Reyes Station gage. Maximum mean daily flows at both locations were 81.3 m^3/s (2870 cfs) and 214 m^3/s (7560 cfs) respectively.

Table 9. Daily average flow and 7 day average flow (in Lagunitas Creek at Samuel P. Taylor State Park) prior to each survey in Devil's Gulch. Average water clarity during each survey and the number of live coho observed in 1997-98 in Devil's Gulch are also shown. A large percentage of the flow in Lagunitas Creek above Devil's Gulch is regulated by releases from Peter's Dam.

Date	Lagunitas Cr. Daily Average Flow m^3/s (cfs)	Lagunitas Cr. 7 Day Average Flow Prior to Survey m^3/s (cfs)	Devil's Gulch Average Water Clarity (cm)	Devil's Gulch Live Coho
Nov 17	1.08 (38)	1.05 (37.2)	20	1
Nov 25	1.3 (46)	1.31 (46.3)	100	4
Dec 3	1.19 (42)	1.49 (52.7)	100	12
Dec 11	0.99 (35)	2.15 (76.0)	60	26
Dec 17	0.99 (35)	1.33 (47.1)	60	18
Dec 31	0.76 (27)	0.71 (25.0)	85	1
Jan 6	1.5 (53)	2.23 (78.6)	n.a.	17
Jan 23	4.93 (174)	14.1 (496.6)	50	0

Area Under the Curve and Peak Live Plus Cumulative Dead Indices

Area Under the Curve

Area Under the Curve (AUC) estimates were generated for live fish observed in the mainstem of Olema Creek, Redwood Creek, and Devil's Gulch. Estimates were calculated for reaches two through four of Olema Creek because this 4.5 km section was sampled during each survey (Figure 11). Residence time (RT) and observer efficiency (OE) were not measured and potential AUC estimates were calculated based on values sampled during each survey (Figure 11). Residence time (RT) and observer efficiency (OE) were not measured and potential AUC estimates were calculated based on values from published coho spawner studies. We reviewed eight studies and found RT values ranging from 8 to 17 days (Table 10). The most frequently reported values were 11 and 13 days. Two of the eight studies reported OE values between 69 and 76 percent (Solazzi et al. 1984; Johnston et al. 1987). To consider a wider range observer efficiencies, we calculated AUC estimates for OE values between 50 and 100 percent.

Population estimates in the Olema Creek section ranged from 56 to 118 fish at 100% OE and 112 to 236 fish at 50% OE (Table 10). Estimates for Redwood Creek ranged between 86 and 183 fish at 100% OE and 172 to 366 fish at 50% OE (Table 11). In Devil's Gulch, AUC estimates using 100% OE ranged from 41 to 87 fish and estimates using 50% OE ranged from 82 to 174 fish (Table 12). Estimates from the most commonly reported OE (70-80%) and RT (11-13 days) values ranged from 91 to 123 fish in Olema Creek, 141 to 190 fish in Redwood Creek, and 66 to 90 fish in Devil's Gulch

Peak Live Plus Cumulative Dead

Because coho return to spawn over a three month period and residence time on the spawning grounds is variable, the same live fish are often double counted during repeated surveys. An index derived from adding the peak number of live fish observed during a single survey to the number of carcasses recovered prior to that date provides a minimum spawner estimate. The peak live plus cumulative dead (PLD) index was 88 on the mainstem of Olema Creek, 58 on the mainstem of Redwood Creek, and 27 on Devil's Gulch (Table 13). The PL index for the tributary and mainstem sections of Olema and Redwood Creek were 104 and 76 respectively.

Review of Historical Spawner Survey Data

Olema Creek Watershed

We reviewed reports and anecdotal accounts from professional biologists to compare the 1997-98 results with previously collected data (Table 13). Surveys have been conducted annually on the mainstem of Olema Creek since 1994-95 but observers focused primarily

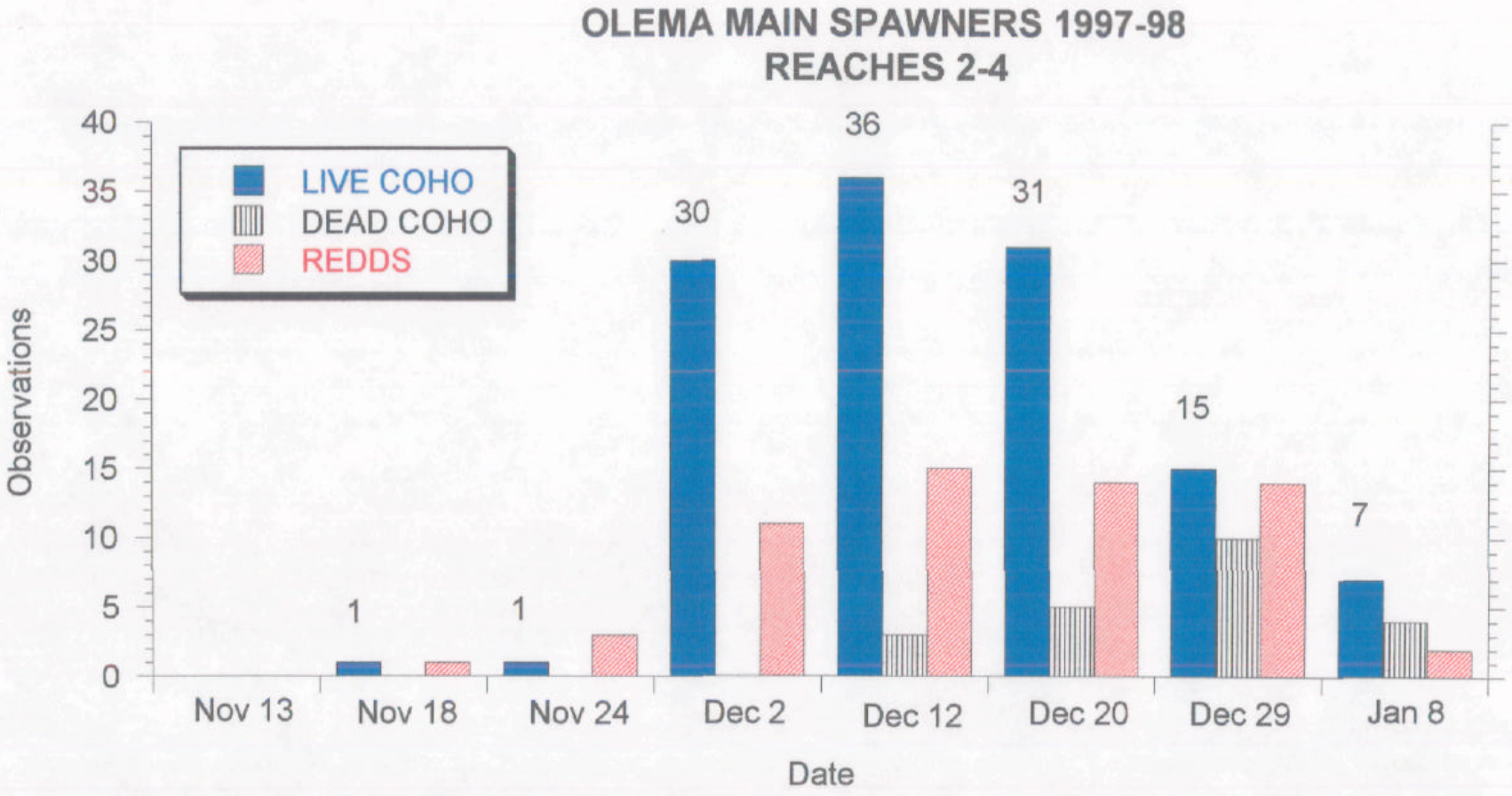


Figure 11. Total live fish, carcass, and redd observations for coho salmon between survey reaches 2 and 4 (kilometer 4 to 11) on the mainstem of Olema Creek.

Table 10. Area Under the Curve (AUC) population estimates for coho salmon adults in reaches 2-4 of Olema Creek during 1997-98. Potential estimates are given for various combinations of average residence time (spawning ground life) and observer efficiency. Neither residence time (RT) nor observer efficiency (OE) were estimated during the surveys. AUC Estimates derived from studies that measured coho RT and OE values are highlighted. Footnotes indicate published sources.

Residence Time (days)	Observer Efficiency					
	100%	90%	**80%[f]**	**70%[c]**	60%	50%
8[a]	118	131	**148**	**169**	197	236
9[b]	105	117	**131**	**150**	175	210
10[C]	95	106	**119**	**136**	158	190
11 [d,e,f]	86	96	**108**	**123**	143	172
12	79	88	99	113	131	158
13 [a,e,f,g]	73	81	**91**	**104**	121	146
14[g]	68	76	**85**	**97**	113	136
15[a]	63	70	**79**	**90**	105	126
16	59	66	74	84	98	118
17[a]	56	62	**70**	**80**	93	112

a/ Irvine etal. (1992)
b/ van der Berghe and Gross (1986)
c/ Flint (1984)
d/ Beidler and Nickelson (1980)
e/ Johnston et al. (1987): 69% observer efficiency
f/ Crone and Bond (1976)
g/ Koski (1966)
h/ Solazzi et al. (1984): 76% observer efficiency

Table 11. Area Under the Curve (AUC) population estimates for coho salmon adults in the mainstem of Redwood Creek during 1997-98. Potential estimates are given for various combinations of average residence time (spawning ground life) and observer efficiency. Neither residence time (RT) nor observer efficiency (OE) were estimated during the surveys. AUC Estimates derived from studies that measured coho RT and OE values are highlighted. Footnotes indicate published sources.

Residence Time (days)	Observer Efficiency					
	100%	90%	**80%[f]**	**70%[c]**	60%	50%
8[a]	183	203	**229**	**261**	305	366
9[b]	163	181	**204**	**233**	272	326
10[C]	147	163	**184**	**210**	245	294
11 [d,e,f]	133	148	**166**	**190**	222	266
12	122	136	153	174	203	244
13[a,e,f,g]	113	126	**141**	**161**	188	226
14[g]	105	117	**131**	**150**	175	210
15[a]	98	109	**123**	**140**	163	196
16	92	102	115	131	153	184
17[a]	86	96	**108**	**123**	143	172

a/Irvine etal. (1992)
b/ van der Berghe and Gross (1986)
c/ Flint (1984)
d/ Beidler and Nickelson (1980)
e/ Johnston et al. (1987): 69% observer efficiency
f/ Crone and Bond (1976)
g/ Koski (1966)
h/ Solazzi et al. (1984): 76% observer efficiency

Table 12. Area Under the Curve (AUC) population estimates for coho salmon adults in Devil's Gulch during 1997-98. Potential estimates are given for various combinations of average residence time (spawning ground life) and observer efficiency. Neither residence time (RT) nor observer efficiency (OE) were estimated during the surveys. AUC Estimates derived from studies that measured coho RT and OE values are highlighted. Footnotes indicate published sources.

Residence Time (days)	Observer Efficiency					
	100%	90%	**80%[h]**	**70%[d]**	60%	50%
8[a]	87	97	**109**	**124**	145	174
9[b]	77	86	**96**	**110**	128	154
10[C]	69	77	**86**	**99**	115	138
11 [d,e,f]	63	70	**79**	**90**	105	126
12	58	64	73	83	97	116
13 [a,e,f,g]	53	59	**66**	**76**	88	106
14[g]	49	54	**61**	**70**	82	98
15[a]	46	51	**58**	**66**	77	92
16	43	48	**54**	**61**	72	86
I7[a]	41	46	**51**	**59**	68	82

a/ Irvine etal. (1992)
b/ van der Berghe and Gross (1986)
c/ Flint (1984)
d/ Beidler and Nickelson (1980)
e/ Johnston et al. (1987): 69% observer efficiency
f/ Crone and Bond (1976)
g/ Koski (1966)
h/ Solazzi et al. (1984): 76% observer efficiency

Table 13. The number of live adult coho salmon, carcasses, and redds observed annually for streams in the Lagunitas, Olema, and Redwood Creek watersheds. To facilitate comparisons between years, the live adult coho numbers are depicted as peak survey counts plus the total number of carcasses recovered to that date. Peak live counts for Olema Creek, Devils Gulch, and San Geronimo Creek represent total live fish observations from one day. Due to the size of the mainstem of Lagunitas Creek, peak mainstem live counts represent totals from consecutive days. Asterisks (*) denote peak live fish counts without accumulated carcass data. Counts based on one survey per year may not represent the true peak number of fish. Additional comments are included as footnotes.

Stream	Year	Number of Surveys	Survey Area (km)	Peak Survey Live Fish Count + Cumulative Dead	Total Carcasses	Total New Redds	Source
Olema Creek mainstem	1994-95	3	13.4	53	1	9	Tomales Bay Assoc.(TBA)
	1995-96	2	13.4	106	37	n.a.	National Park Service (NFS); TEA
	1996-97	2	15.6	174	16	n.a.	NFS; TEA
	1997-98	8	13.4	88	39	126	NFS
Lagunitas Creek mainstem	1982-83	6	13.3	n.a.	n.a	65	Bratovich and Kelly 1988
	1983-84	6	13.3	n.a.	n.a.	26	Bratovich and Kelly 1988
	1991-92	1	13.3	n.a.	n.a.	34	Wise 1992
	1995-96	10	13.3	129*	n.a.	70	Trihey & Associates 1996
	1996-97	8	13.3	170*	23	98	Trihey & Associates 1997
	1997-98	10	13.3	46	27	80	Marin Municipal Water District (MMWD) 1998

Table 13. continued

Stream	Year	Number of Surveys	Survey Area (km)	Peak Survey Live Fish Count + Cumulative Dead	Total Carcasses	Total New Redds	Source
Devil's Gulch	1948[a]	1	2.6	174*	n.a.	n.a.	CDFG; A. Giddings pers. comm.
	1957-58[b]	2	2.4	100*	n.a.	74	CDFG; E. Gerstung pers. comm.
	1960-61	1	2.6	77*	n.a.	n.a.	CDFG; E. Gerstung pers. comm.
	1961-62	1	2.6	70*	n.a.	n.a.	CDFG: E. Gerstung pers. comm.
	1964-65	1	1.6	91	76	n.a.	CDFG; E. Gerstung pers. comm.
	1965-66	2	2.6	130*	n.a.	n.a.	CDFG; E. Gerstung pers. comm.
	1976-77	1	2.4	100	90	n.a.	CDFG; E. Gerstung pers. comm.
	1982-83	6	2.4	n.a.	n.a.	23	Bratovich and Kelly 1988
	1983-84	6	2.4	n.a.	n.a.	11	Bratovich and Kelly 1988
	1995-96	6	2.4	19	n.a.	10	Trihey & Associates 1996
	1996-97	3	3.2	47	20	42	Trihey & Associates 1997; NFS
	1997-98	8	3.2	27	9	46	NFS 1998

a/ peak live fish count includes both coho and steelhead b/ estimated number of live fish

Table 13. continued

Stream	Year	Number of Surveys	Survey Area (km)	Peak Survey Live Fish Count + Cumulative Dead	Total Carcasses	Total New Redds	Source
San Geronimo Creek	1982-83	6	6.7	n.a.	n.a.	51	Bratovich and Kelly 1988
	1983-84	6	6.7	n.a.	n.a.	7	Bratovich and Kelly 1988
	1991-92	2	6.7	62	n.a.	7	Wise 1992
	1995-96	6	6.7	19*	n.a.	6	Trihey & Associates 1996
	1996-97	3	6.7	154*	n.a.	115	Trihey & Associates 1997
	1997-98	9	6.7	64	37	108	Marin Municipal Water District (MMWD) 1998
Totals for Lagunitas Creek watershed [c]	1982-83°	6	22.4	n.a.	n.a.	139	Bratovich and Kelly 1988
	1983-84 [c]	6	22.4	n.a.	n.a.	44	Bratovich and Kelly 1988
	1991-92°	1	20.0	n.a.	n.a.	41	Wise 1992
	1995-96 [d]	10	36	290	n.a.	86	Trihey & Associates 1996
	1 996-97 [d]	8	36	525	92	254	Trihey & Associates 1997
	1 997-98 [d]	10	36	241	112	360	Marin Municipal Water District (MMWD) 1998; NPS 1998

c/ Survey totals for mainstem Lagunitas Creek, Devil's Gulch, and San Geronimo Creek. Devil's Gulch was not surveyed in 1991-92. d/ Survey totals for mainstem Olema Creek, Olema Creek tributaries, mainstem Lagunitas Creek, Devil's Gulch, and San Geronimo Creek.

Table 13. continued

Stream	Year	Number of Surveys	Survey Area (km)	Peak Survey Live Fish Count + Cumulative Dead	Total Carcasses	Total New Redds	Source
Redwood Creek watershed	1969	1	3.2	24	4	n.a.	CDFG; Reineck and Paulsen 1978
	1977-78	1	3.2	36	3	n.a	CDFG; Reinick and Paulsen 1978
	1985-86	1	7.2	50	n.a.	n.a.	CDFG; B. Cox pers comm.
	1994-95	5	7.7 [d]	58	22	n.a.	NPS 1995
	1995-96	5	7.7	27	18	n.a.	NPS 1996
	1996-97	6	7.7	57	15	n.a.	NPS 1997
	1997-98	7	8.7 [e]	58	30	84	NPS 1998

d / Includes the mainstem of Redwood Creek and Fern Creek.
e / Includes the mainstem of Redwood Creek, Fern Creek, and Kent Creek.

on counting live fish and carcasses prior to 1997-98. The PL index values for the mainstem of Olema Creek ranged from 53 in 1994-95 to 174 in 1996-97. The majority of the 1997-98 spawners were the progeny of the 1994-95 run. Although many factors control the population size of a year class, the low numbers offish in 1994-95 appear to be reflected in the PLD index value for 1997-98. More surveys were conducted in 1997-98 than in previous years. The numbers of carcasses recovered in each year was low.

Because the same reaches were surveyed each year, we were able to compare the distribution of spawners throughout the mainstem of Olema Creek. In 1997-98 and 1994-95, the highest percentages of live fish were observed in reaches three and six and during all four years the greatest numbers offish were observed between reaches three and six. Although it was not surveyed in 1996-97, no more than one percent of the live fish were observed in reach one during 1994-95, 1995-96, and 1997-98.

Lagunitas Creek Watershed

Lagunitas Mainstem

The Marin Municipal Water District (MMWD) collected spawner survey data on the mainstem of Lagunitas Creek between 1982-84, 1991-92, and 1995-98 (Table 13). With the exception of the 1991-92 season, multiple surveys were conducted each year in the same 13.3 km reach. Live fish and carcasses were not counted prior to 1995-96 but redds were counted each year. The PLD index values for the 1995-96, 1996-97, and 1997-98 runs were 129, 170, and 46 respectively. Redds counts ranged from 26 in 1983-84 to 98 in 1996-97.

Devil's Gulch

Devil's Gulch has the longest period of spawner survey records in the Lagunitas Creek watershed. California Department of Fish and Game biologist Eric Gerstung and warden Al Giddings noted live coho and steelhead observations from 1948 to 1977 (Table 13). Consultants for MMWD conducted surveys from 1982-84 and 1995-97. The NFS expanded the sampling area further upstream in 1996-97. Prior to 1982-83, no more than two surveys were conducted in a single season and carcasses and redd data were not consistently collected. During a single survey in 1948, 174 coho and steelhead were counted in 2.6 km reach. Between 1957-58 and 1976-77, peak counts of live coho ranged between 70 and 130 fish. Between 1995-96 and 1997-98, PL index values ranged from 19 to 47 fish. From 1982-83 to 1997-98, the total number of redds ranged between 10 and 46.

San Geronimo Creek

San Geronimo Creek is the second largest tributary of Lagunitas Creek (Olema Creek is the largest). A 6.2 km reach of San Geronimo Creek was surveyed by MMWD in 1982-84, 1991-92, and 1995-97. Redds were counted each year but live fish sightings were not

recorded until 1991. Between 1991-92 and 1997-98 the PL index values ranged from 19 to 154 fish. The number of redds ranged between 6 and 115 from 1982-83 to 1997-98.

Lagunitas and Olema Creek Watershed Totals

We summed the total carcass, redd, and PLD index data from the mainstem of Olema Creek, seven Olema Creek tributaries, the mainstem of Lagunitas Creek, Devil's Gulch, and San Geronimo Creek for the 1982-84, 1991-92, and 1995-97 seasons (Table 13). Olema Creek data was not available until 1995. Redd data was available each season but live fish data was not collected until 1995. The PLD index values and redd counts from 1995-96 to 1997-98 ranged between 241 and 525 fish and from 86 to 360 redds.

The high relative abundance of the 1996-97 run was evident throughout the Lagunitas Creek Watershed. PLD index values were the highest in recent years for the mainstem of Lagunitas Creek, Devil's Gulch, and San Geromino Creek.

Redwood Creek Watershed

Although NPS employees have noted fish observations in Muir Woods since 1944, coordinated efforts to count spawners were not initiated until 1994. The California Department of Fish and Game conducted two surveys in the Muir Woods portion of the stream in 1969 and 1977-78 (Table 13). In 1985-86, an extended survey was conducted through Mt. Tamalpias State Park. Since 1969, PL index values have ranged between 24 and 58. The total number of carcasses collected from 1994-95 to 1997-98 ranged from 15 to 30. Redds were not counted until 1997-98.

Comparison of 1997-98 Spawner Densities

We compared the density of live fish, carcasses, and redds for Olema Creek, Lagunitas Creek, Devil;s Gulch, San Geronimo Creek, and Redwood Creek. Thirty six kilometers of spawning habitat were surveyed annually in the Lagunitas Creek watershed between 1995-96 and 1997-98. The watershed total PLD value for 1996-97 was 525 fish or nearly 15 fish per kilometer. Densities in 1996-97 based on PLD values were 13 fish/km in the mainstems of Olema and Lagunitas Creeks, 15 fish/km in Devil's Gulch, and 23 fish/km in San Geronimo Creek, hi 1997-98, the highest densities offish were also observed in Devil's Gulch and San Geronimo Creek. San Geronimo Creek had the highest number of live fish plus cumulative dead during the peak of the run (10), total carcasses (5.5) , and total redds (16.1) per kilometer (Table 14). Devil's Gulch had the second highest density of live plus cumulative dead fish and total redds. Densities in the mainstem of Olema and Redwood Creeks were similar. The mainstem of Lagunitas Creek had the lowest peak live, carcass, and redd densities.

Table 14. Density (# / km) of Peak Live Plus Cumulative Dead Index (PLD), total carcass, and total redds for the mainstem of Olema Creek, Devil's Gulch, Lagunitas Creek, San Geronimo Creek and Redwood Creek during 1997-98. Lagunitas and San Geronimo Creek data was provided by the Marin Municipal Water District (Andrew 1998).

Stream	Density (# / km)		
	PLD Index	Total Carcasses	Total Redds
Olema Cr. mainstem	7	2.9	9.4
Lagunitas Cr. mainstem	4	2.0	6.0
Devil's Gulch	8	2.8	14.4
San Geronimo Cr.	10	5.5	16.1
Redwood Cr.	7	3.4	9.7

DISCUSSION

The use of visual survey counts as indices of abundance requires knowledge of the relationship between the index and actual escapement (Johnston et al. 1987). Although live fish, redds, and carcasses were sampled repeatedly over large portions of each basin, it is not possible to assess the accuracy of the data without comparison to independent measures of abundance such as trap counts or mark recapture estimates. Through our current survey practices we cannot test the assumptions of peak live count and area under the curve estimates and observer variability may limit the comparability of redd counts among streams and years.

The application of visual spawner survey indices is guided by four assumptions: if index reaches are used then the distribution of fish in a watershed should be constant, peak counts should be consistently proportional to the total run size, observer efficiency should be similar between surveys, and the probability of an individual fish being observed should be similar for all levels of abundance (Beidler and Nickelson 1980). By sampling large contiguous sections of the mainstem of Olema Creek, Redwood Creek, and Devil's Gulch we circumvented the first assumption. With the exception of reach seven on Olema Creek, we sampled the entire portion of each stream that was accessible to coho for spawning.

We cannot evaluate the assumption that peak/total ratios were consistently proportional because we have no reliable estimates of total population size. In Oregon's Alsea River watershed, coho peak/total ratios ranged from 0.20 to 0.74 and averaged 0.34 over a 14 year period (Beidler and Nickelson 1980). The peak/total ratio from a single year of observation on the South Fork Noyo River, California was 0.26 (Maahs and Gilleard 1994). The relationship of peak live to total counts can substantially influence the conclusions drawn from spawner survey data. While Beidler and Nickelson (1980) found peak counts well correlated with the total run size over a 14 year period, year to year variability was large. Because annual variability was high, they found that chinook population estimates in Anvil Creek were similar in 1978 an 1979 but PL index values were twice as high in 1978 as 1979. A study in Washington streams suggested that variation in the ratios between visual index counts and actual escapements were ± 20 to 50% (Flint 1984). Because the AUC method uses observations from the entire spawning period, estimates are not effected by the consistency of peak/total ratios.

The third assumption, consistent observer efficiency, effects the reliability of both PL and AUC estimates. Although we did not measure observer efficiency (the relationship between true numbers of fish and visual counts) or inter-observer variability, similar studies in small streams have found that efficiency is generally high and variability is low (Solazzi 1984; Irvine et al. 1987; Shardlow et al. 1987). However, the physical characteristics of each stream were different and environmental conditions at the time of each survey may have influenced efficiency and variability. Average water clarity was lowest and most variable on Olema Creek (53 cm, CV= 44%) and highest and least

variable on Redwood Creek (104 cm, CV=28%). Mean daily flows on survey dates were similar in Olema (0.51 m3/s, CV=71%) and Redwood (0.47 m3/s, CV=74%) Creeks. The patterns of precipitation and timing of the runs in 1997-98 created amenable survey conditions. It was likely that most coho were finished spawning prior to the onset of the strong January and February storms. Although Olema Creek carries a high suspended sediment load and clears slowly after storms, visibility was severely limited during only the first two surveys when few fish were present. During the peak of the run, clarity exceeded 70 cm and the bottoms of most pools were visible.

Observer experience also impacts efficiency and variability. All NFS personnel and volunteers attended a one day training course prior to initiating the surveys and many volunteers had conducted surveys in previous years. Volunteers were accompanied in the field at least once by CSRP biologists and many surveys were conducted entirely by NFS staff. To reduce variability, we attempted to use experienced volunteers more frequently and encouraged observers to "adopt" particular reaches. By using teams of observers, walking in the stream channel, and dislodging fish from cover with survey staffs we observed many fish that would have been otherwise undetected. Shardlow et al. (1987) demonstrated that workers with prior experience obtained similar results and Johnston et al. (1987) found that counts on the same reach by two different crews were highly correlated. Using the same protocol employed in our 1997-98 surveys, Johnston et al. (1987) found observer efficiency averaged 69% and Solazzi (1984) reported 76% efficiency
.
Satisfaction of the fourth assumption, constant probability of observing a given fish under different levels of abundance, is also related to observer efficiency and variability. The observers expended equal effort during each survey, regardless of abundance, and any changes in the probability of detecting fish were probably not related to observer bias. However, early arriving fish appeared to be more secretive and we found less fish seeking cover during the peaks of the run. Most of the fish observed during the peaks were actively spawning and less inclined to seek cover as observers approached them. The PL index is also influenced by the probability of observing accumulated carcasses. At low spawner densities, carcasses may be removed rapidly by scavengers and index values could be negatively biased (Beidler and Nickelson 1980).

Visual surveys are commonly used to evaluate coho escapement yet time and funding rarely permit an assessment of the above assumptions. Several studies have compared AUC and PL estimates to trap results and mark recapture estimates (Johnston et al. 1987; Irvine et al. 1992; Maahs and Gilleard 1994). Unfortunately, it is impossible to directly relate these results to our current monitoring efforts. Variability in environmental conditions, habitat, and run characteristics in each watershed demand unique investigations. Comparative studies suggest that while results are variable visual surveys are generally neither precise nor accurate. In an investigation of various survey designs in British Columbia, Johnston et al. (1987) found that AUC and PL estimates accounted for 50% of the probable escapement and coefficients of variation were 50%. Irvine et al. (1992) found that AUC estimates produced from a stratified index sampling design were

similar to mark-recapture estimates for three year old adults but grossly underestimated the number of jacks. Less than 50% of the adult coho released above the Noyo River Egg Taking Station in 1991-92 were accounted for by AUC estimates (Maahs and Gilleard 1994).

Although the evaluation of annual trends based on visual indices is problematic, the data collected in 1997-98 may be sufficient to indicate gross trends in relative abundance. Surveys were conducted frequently over the majority of the available spawning habitat, environmental conditions were favorable for most of the season, and well trained observers diligently counted live fish, carcasses, and redds. However, the magnitude of change that can be detected using the PLD index is unknown. The preceding literature review suggests that changes in PLD index values of no less than 50% might indicate differences in abundance. In the three spawning seasons prior to 1997-98 on Olema Creek, no more than three surveys were conducted per year and we can not determine if the true peak was measured. If observers captured the peaks and peaks were proportional to the total run size, PLD index values suggest that spawners were three times as abundant in 1996-97 (174 fish) as 1994-95 (53 fish). The PLD index value for 1997-98 (88) was approximately 50% of the 174 fish observed in 1996-97. The apparent low abundance of spawners in 1994-95 was reflected three years later in the 1997-98 run. Although the identification of this brief trend may demonstrate that our methods are detecting relative levels of abundance, more annual data is needed to confirm the observations.

The spawner survey data collected on Redwood Creek between 1994-95 and 1997-98 permitted a comparison of AUC and PLD estimates. During 1994-95, 1996-97, and 1997-98 the PLD index values were 58, 57, and 58 respectively. Using an arbitrary 13 day residence time and 80% observer efficiency, the AUC estimates for the same years were 160, 156, and 141. Both the PLD and AUC estimates showed that the number of spawners differed little between years. The similarities may also indicate that peak / total ratios in Redwood Creek were consistent each year. Despite the similarities in the data, it is still not possible to accurately estimate population sizes.

Total carcass counts did not show the same trends as PLD values in Olema, Lagunitas and Redwood Creeks. In Olema Creek, the PLD value for 1997-98 was less than half the 1996-97 index yet twice as many carcasses were recovered in 1997-98 as 1996-97. The PLD index value in Lagunitas Creek was almost four times greater in 1996-97 than 1997-98 yet the total number of carcasses recovered was almost the same in both years. Likewise on Redwood Creek twice as many carcasses were recovered in 1997-98 as 1996-97 yet the PLD values only differed by one fish. It would therefore appear that total carcass counts are an unreliable index of escapement. Scavengers likely removed carcasses soon after spawners died and the interval between surveys was too large to recover most dead fish. During a mark-recapture study on the Lower South Fork Noyo River, Maahs and Gilleard (1994) found that carcass retention rates ranged from 10 to 25% after seven days and from 2 to 12 % after 14 days. In addition to providing poor indices of abundance, low carcass retention rates may affect estimates of spawner sex

ratios. We have no evidence to suggest that retention rates differed for males, females, and jacks but very small samples sizes make any estimate of sex ratios questionable. On Devil's Gulch only eight carcasses were recovered, two of which could not be identified.

Because females construct multiple redds and redds can be difficult to identify, redd counts are not a reliable indicator of annual trends in population size. Coho females often construct "false" redds. Briggs (1954) found that only 54% of coho redds contained eggs. Although they are often obvious, redds can be subtle features of the stream bed and only experienced observers identify them consistently. Because volunteers conducted many surveys, we are not completely confident that redds were accurately counted. However, throughout the 1997-98 season CSRP biologists surveyed each reach and we probably counted most redds. Redd count data reveals more about spawner distribution than abundance. Unless fish are observed while spawning, live fish data does not indicate spawning habitat use. Prior to the 1997-98 surveys, redd data was not collected in either Olema or Redwood Creeks. Efforts should be made to continue the collection of redd distribution data.

CONCLUSION

The 1997-98 spawner surveys were the most comprehensive to date. Olema Creek, Devil's Gulch, and Redwood Creek were surveyed frequently by NFS staff and well trained volunteers. The collection of frequent live fish and carcass data permitted the computation of Peak Plus Cumulative Dead and Area Under the Curve Index values. However, the validity of the PLD and AUC estimates can not be determined without testing assumptions and comparison with more accurate measures of abundance. Redd data was collected for the first time by NPS staff this season and should be collected in future surveys.

Although each watershed received heavy El Nino precipitation during January and February, flow and water clarity were conducive to the collection of survey data for the majority of the coho spawner season. The record setting flows and rainfall altered the streambed extensively and most redds were no longer visible after the storms. It was likely that scour and fill destroyed many coho redds but we have no data to determine redd survival.

Despite the tenuous nature of PLD index values and inconsistencies in data collection, our review of historical spawner abundance data indicated substantial variability in recent years. Long-term historical information for Devil's Gulch indicated a preciptiuous decline over the past 50 years. Escapement in 1997-98 may have been less than 50% of the 1996-97 escapement in Olema Creek, Lagunitas Creek, Devil's Gulch, and San Geronimo Creek. Abundance in 1996-97 appeared to the highest in recent years. Unlike streams of the Lagunitas Creek watershed, escapement in Redwood Creek was lowest in 1995-96

and the same in 1996-97 and 1997-98. AUC estimates also showed the same trend as PLD index values in Redwood Creek.

High effort and favorable environmental conditions were primarily responsible for the success of the 1997-98 season. The NFS should collect data in future seasons using the same methodology in the same survey reaches to insure comparability of the data. Due to its length (13.4 km), the mainstem of Olema Creek is difficult to sample in a single day. More effort should be expended to complete sampling on a single day.

The ultimate goal of escapement monitoring is to detect changes in population size over time. The current foot surveys methods may only permit the detection of gross annual differences, perhaps in excess of 50%. More precise methods will need to be employed if a subtle detection of change is desired. While our current survey practices may provide some index of abundance, we have no way of determining the accuracy of the estimates or total adult population sizes.

REFERENCES

Anderson, D. and H. McGuire. 1994. Redwood Creek basin 1991-1992 spawning and carcass survey; annual progress report. National Park Service, Resource Management Division, Redwood National Park, Arcata, CA. 32 p.

Andrew, G. 1998. Lagunitas Creek coho salmon spawner survey report fall and winter 1997-98. Marin Municipal Water District, Corte Madera, CA. p.

Beidler, W. M. and T. E. Nickelson. 1980. An evaluation of the Oregon Department of Fish and Wildlife standard spawning fish survey system for coho salmon. Oregon Department of Fish and Wildlife, Information Report Series, Fisheries 80-9. 23 p.

Bratovich, P. M. and D. W. Kelley. 1988. Investigations of salmon and steelhead in Lagunitas Creek, Marin County, California, Volume 1; migration, spawning, embryo incubation and emergence, juvenile rearing, emigration. Report prepared for the Marin Municipal Water District, Corte Madera, CA. 187 p.

Briggs, J.S. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. California Fish and Game Bulletin 94. 62 p.

Crone, R. A. and C. E. Bond. 1976. Life history of coho salmon in Sashin Creek, Southeast Alaska. Fish Bulletin 74:897-923.

Downie, S. and G. Peterson. Undated. Spawning Inventory Methods. California Department of Fish and Game, Redway, CA.

Flint, T. 1984. A comparison of stream indexing methods to estimate coho escapements in Harris Creek, 1980-1983. Canadian Technical Report, Fisheries and Aquatic Sciences 1326:149-159.

Fong, D. 1995; 1996; 1997. Redwood Creek spawner and carcass survey, annual report. National Park Service, Golden Gate National Recreation Area, Division of Resource Management and Planning, Sausalito, CA. 8 p.

Irvine, J. R., R. C. Bocking, K. K. English, and M. Labelle. 1992. Estimating coho salmon (Oncorhyncus kisutch) spawning escapements by conducting visual surveys in areas selected using stratified random and stratified index sampling designs. Canadian Journal of Fisheries and Aquatic Sciences 49:1972-1981.

Johnston, N. T., J. R. Irvine, and C. J. Perrin. 1987. Instream indexing of coho salmon *(Oncorhyncus kisutch)* escapement in French Creek, British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences 1537. 32 p.

Maahs, M. and J. Gilleard. 1994. Anadromous salmonid resources of Mendocino County coastal and inland rivers, 1990-91 through 1991-92; An evaluation of rehabilitation efforts based on caracass recovery and spawning activity. Salmon Trailers Marketing Association, Fort Bragg, CA. 60 p.

Moring, J. R. and J. R. Lantz. 1974. The Alsea watershed study; effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part 1, biological studies. Oregon Department of Fish and Wildlife, Fisheries Resources Report 9.

Shardlow, T., R. Hilborn, and D. Lightly. 1987. Components analysis of instream escapement methods for Pacific salmon *(Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 44:1031-1037.

Solazzi M. F. 1984. Relationships between visual counts of coho salmon *(Oncorhyncus kisutch*) from spawning fish surveys and the actual number offish present, p. 175-186. In P. E. K. Symons and M. Waldichuk (Eds.) Proceedings of the workshop on stream indexing for salmon escapement estimation. Canadian Technical Report of Fisheries and Aquatic Sciences 1326:258 p.

Trihey and Associates, Inc. 1996 . Lagunitas Creek coho salmon spawner survey report fall and winter 1995-96. Marin Municipal Water District, Corte Madera, CA. 17p.

Trihey and Associates, Inc. 1997 . Lagunitas Creek coho salmon spawner survey report fall and winter 1996-97. Marin Municipal Water District, Corte Madera, CA. 17p.

van den Berghe, E. F. and M. R. Gross. 1986. Length of breeding life of coho salmon *(Oncorhyncus kisutch*). Canadian Journal of Zoology 64:1482-1486.

Wise, L. 1992. Memorandum - Lagunitas Creek coho spawner survey; Appendix K *In.* Habitat recommendations for Lagunitas Creek, Don Kelley and Associates and Entrix, Inc. for Marin Municipal Water District, Corte Madera, CA.

PERSONAL COMMUNICATIONS

Cox, Bill. District Fishery Biologist, California Department of Fish and Game, Region 3 unpublished memorandum January 25, 1986.

Reineck, R. C. and I. V. Paulsen. California Department of Fish and Game, Menlo Park, unpublished memorandum January 12, 1978.

Giddings, Al. Lt. Game Warden, California Department of Fish and Game (retired), Region 3, memorandum, 1992.

Gerstung, Eric. Associate Fishery Biologist, California Department of Fish and Game, Region 3, memorandum October 14, 1997.

APPENDIX A

The Coho and Steelhead Restoration Project Spawner Survey Protocol Field Procedure

NFS Coho and Steelhead Restoration Project Spawner Survey Field Procedure

Instructions

CRSP biologists will determine survey dates and assign observers to reaches. For safety, at least two people should conduct each survey. Begin the survey from the downstream end of a predetermined reach and walk upstream. Walk in the channel and on the banks, avoiding pool tailouts and redds. Inspect the stream for live fish and carcasses by probing banks, woody debris, and pools with a 2 m survey rod (see section on equipment). It is important to remain observant and use your senses while conducting the survey. Look upstream ahead of you, fish may seek cover when observers are as much as 30 m downstream. Females splash when constructing redds and fish can be heard migrating through riffles. Carcasses often emit a pungent odor. The techniques for collecting live fish, carcass, and redd data are described in reference to the Spawner Survey Data Sheet (Figure A-l). Observing spawning fish is fascinating and you will undoubtedly want to learn more about salmon behavior. Appendix C contains sections of a review article on coho salmon biology (Sandercock 1991). Additional information can be obtained from the CSRP office.

Initial Survey Information

The Spawner Survey Data Sheet contains the following fields for recording information at the beginning and end of each survey reach. All information must be written in pencil on water proof copies of the data sheet provided by the CSRP staff. Please write legibly.

Stream: Record the full name of the stream you are surveying.

Reach: Record the reach number.

Date: Enter the survey date in Month / Day / Year format.

Weather: Record the weather conditions at the time of the survey.

Start Time: Enter the time at the beginning of the survey.

End Time: Enter the time at the end of the survey.

Observers: Enter the first initial and last name of all crew members.

Recorder: Enter the name of the person who is writing the data.

Tel: Enter the telephone number of the recorder (data sheets can become illegible).

Water Temp: Record the water temperature in either Celsius (C) or Fahrenheit (F) using thermometers provided by the CSRP staff.

Water Clarity: Measure water clarity in a pool by noting the depth at which the bottom of the marked survey rod is no longer visible (to the nearest 10 centimeters).

Stage: Some stream reaches have staff gages (graduated plates) to measure water level. If you encounter a gage on your survey, record the water level to the nearest one hundredth of a foot and the time of your observation.

Location

Record the location of all live fish, carcasses, and redds in reference to the 100 m stream section markers. The markers are aluminum tags with plastic survey flagging that have been attached to trees along the stream bank, hi areas without trees, the tags were placed on steel "rebar" stakes and driven into the bank. Each tag is imprinted with a unique code that describes the watershed, stream, and distance from the stream mouth.
More specifically, the identification scheme is a set of three separate two or three-digit codes.

##-##

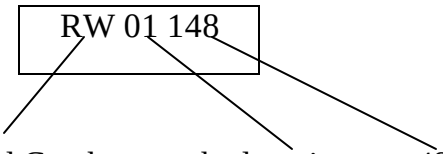
The first code is the watershed designation. The two-letter abbreviations are:

Lagunitas Creek	LG
Olema Creek	OL
Pine Gulch Creek	PG
Redwood Creek	RW

The second numerical code identifies the specific stream. The main-stem is always designated as 01. The tributary codes are listed on maps for each watershed and will be provided by the CSRP staff.

The third numerical code identifies the stream segment and corresponds with the measured linear distance upstream from the mouth. The beginning point for each of the segmented streams (mouth or tributary) has been labeled as 00 (meter 0). The first 100-m

segment receives the code 01. The fifteenth segment (1500 m upstream from the mouth) receives the code 15. For example, a monument tag may appear as:



The translation is Redwood Creek watershed, mainstem, 4800 meters.

When recording spawner survey information you only have to use the last two or three digits of the code (the hundreds of meters upstream). Record an observation as these last two or three digits, on the *closest downstream* tag, plus your estimated distance upstream. For example, if you find a redd 40 m above tag RW 01 48 you would note the location as 48 + 40. Each row on the data sheet should contain the location of a single observation (either a live fish, carcass, or redd). If there are multiple observations at a single location, repeat the location information on each new row. When a fish is observed at a redd, both the live fish and redd information should be included on the same row.

If you cannot locate a tag within 100 m, please note your approximate location in the comments section of the data sheet. Following the large El Nino driven storms of 1997-98, many tags were destroyed. The CSRP has attempted to replace most of the missing tags. If large portions of a survey reach have missing tags, please clearly note the missing tag numbers and reference your live fish, carcass, and redd observations to permanent landmarks such as bridges and buildings.

Species and Sex Identification

Place a check mark in one of the three categories in the species column of the data sheet. All observers will be trained in species identification. However, it is often difficult to identify spawning fish in the field. Use the ? option if you are unable to identify the species. A comprehensive spawning fish identification key, prepared for the Mattole River in northwestern California, is included in Appendix B. The key provides guidance for both live fish and carcasses. Although chinook (king) salmon are included in the key, they occur only rarely in our project streams. Appendix A also includes a less detailed one page summary of coho and steelhead physical characteristics that should be carried in the field by all inexperienced teams of observers.

Section III of the key describes distinguishing sexual characteristics. As the key suggests, cutting open the body cavities of carcasses to expose the gonads greatly facilitates identification. Most coho salmon are three years old at spawning. However, a variable proportion of precocial two year old males also return to spawn. These smaller males are commonly referred to as "jacks". Age can not be accurately determined without carefully

analyzing annual growth rings on scales. However, most jacks are less than 50 cm (20 in) long and are much smaller than the three year olds.

Live Fish

Note the sex and approximate length to the nearest 5 cm of all live fish. If you cannot positively identify a fish's sex, use the ? option. If possible, please try not to disturb spawning fish. Actively spawning fish can be observed safely from a vantage point on the bank.

Carcasses

For all carcasses, note the sex and measure the fork length (tip of the jaw to fork of the tail) in centimeters using the survey rod provided by the CSRP. To confirm the gender of the carcass, slice open the body cavity beginning at the anus and inspect the gonads (Appendix B). Note the approximate number of eggs retained by the females. In the comments section of the data sheet, note the general condition of the carcass (e.g. fresh intact or skeleton). If only a partial length is possible, please make remarks on the sheet.

In addition to counting and noting the location of carcasses, the CSRP is also interested in collecting tissue samples and scales for genetic and age analysis. The removal of tissue will also serve as a mark to prevent double counting of carcasses in subsequent surveys. The genetic analyses are being performed by researchers at the University of California's Bodega Marine Laboratory. Inspect the carcass for holes punched in the operculum (Figure A-2). If the fish has been marked, note the number of punches from one side of the fish in the data sheet column labeled ***Recap Code.*** If the fish has no marks, perform the following procedure:

Tissue and Scale Sample Collection

The following supplies will be provided for sample collection:

- Hole Punch
- Filter Paper
- Coin Envelope
- Tweezers

Tissue is removed from both opercula (gill covers) with a hole punch. The number of punches corresponds to the week of survey. CSRP staff members will tell you the number of punches before you begin. Record the number of punches in the ***Mark Code*** column of the data sheet. Use the tweezers to remove the punches and place the tissue in a folded piece of filter paper. Place the sample in the coin envelope and write the name of the stream, reach, date, collector, species, length, sex, and any notes on the envelope. Rinse the hole punch in the stream after sampling each carcass and insure that it no longer contains any tissue. Use the tweezers to remove 5 to 10 scales from the side of side fish between the lateral line and dorsal fin (Figure A-2). Place the scales in a folded

piece of filter paper and drop them into the same envelope. Because fungal growth degrades the quality of the samples store them in a dry environment. After the CSRP staff collects the samples from you, they will be stored in a dessicator.

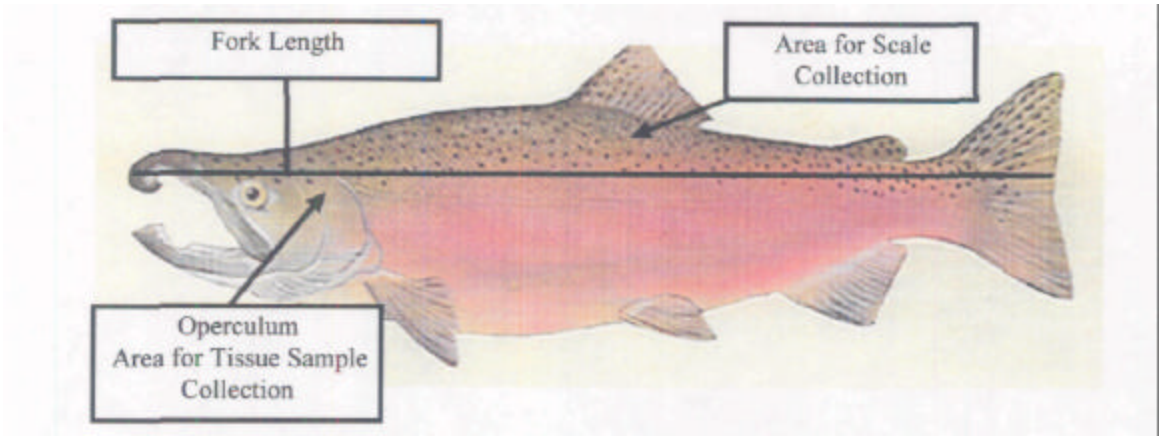


Figure A-2. Illustration of male coho salmon showing body locations for scale and tissue sample collection (drawing by R. Pittard, 1990). Appendix A contains a more detailed illustration of salmonid morphology.

Redds

The CSRP staff will train observers in redd identification. However, after storms areas of excavated gravel are often difficult to distinguish from the surrounding riffle and females may construct numerous "false" redds before choosing a suitable spawning site. Use the ? option in the data sheet column labeled Def (definite) / ? if you are not certain that a feature is actually a redd. Use the survey rod to measure the total length (top of pit to end of tail spill) and average width in meters (Figure A-3). Do not step on redds. The eggs are buried beneath the tail spill. Each redd should be marked with plastic survey flagging to prevent double counting and trampling in subsequent surveys. Write the date and location on a piece of flagging and tie it to vegetation (a few feet above the water) near the redd. If there are numerous redds at a particular location, write the number of redds on the flag. *If there is flagging at the location from a previous survey conducted this season, hang a new flag only if there has been recent excavation. Please make notes in the comment section if numerous redds are observed at the same location.*

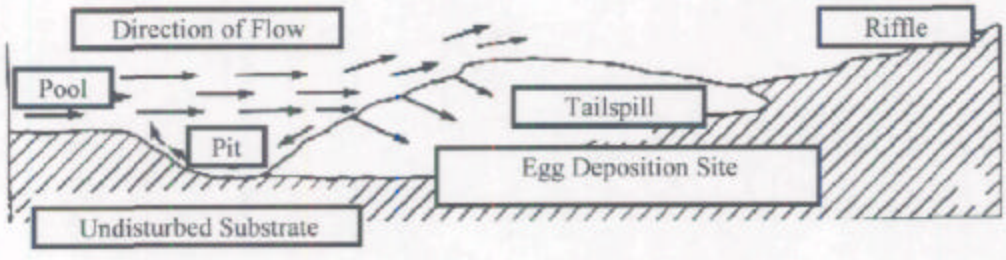


Figure A-3. Cross section of a redd (from Sandercock 1990).

Equipment List

Each team of observers should receive the following items from the CSRP office:

- Clipboard and Water Proof Copies of the Data Sheet
- Pencils
- 2m Graduated Survey Rod
- Chest Waders or Hip Boots
- Polarized Sun Glasses
- Hole Punch
- Tweezers
- Knife
- Coin Envelopes
- Filter Paper
- Plastic Bags
- Plastic Survey Flagging
- Sharpie Water Proof Pen

APPENDIX B

Water Year 1998 Hydrographs for Olema and Redwood Creeks

Stream gauge locations are described in the methods and more detail can be found in:

Ketcham, B.J. 1998. Hydrologic Monitoring Station Information Summary. National Park Service, Coho and Steelhead Restoration Project, Point Reyes National Seashore, Point Reyes Station, CA 94956.

ERROR CODES

3 - Program Table full
4 - Intermediate Storage full
5 - Final Storage Area 2 not allocated
8 - CR10X was reset by watch dog timer
9 - Insufficient Input Storage
10 -- Low battery voltage
11 - Attempt to allocate unavailable storage
12-- Duplicate *4 ID
20 - Subroutine encountered before END of previous subroutine
21 - END without IF, LOOP, or SUBROUTINE
22 - Missing END
23 - Non-existent SUBROUTINE
24 - ELSE in SUBROUTINE without IF
25 - ELSE without IF
26 - EXIT LOOP without LOOP
27 - IF CASE without BEGIN CASE
30 - IFS and/or LOOPS nested too deep
31 - SUBROUTINES nested too deep
32 - Instruction 3 and interrupt subroutine use same port -
33 - Cannot use control port 6 as counter with Instruction 15 or SDM
40 - Instruction does not exist
41 - Incorrect Execution Interval
60 — Insufficient Input Storage
61 - Burst Measurement Scan Rate too Short
62 - N<2 in FFT

•DMode Errors
94 - Program storage area full
95 - Flash program does not exist
96 - Addressed device not connected
97 - Data not received within 30 seconds
98 - Uncorrectable errors detected
99 - Wrong file type or editor error

J

DAY OF YEAR CALENDAR

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
JAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
FEB	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60		
MAR	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83*	84	85	86	87	88	89	90
APR	91	92	93	49	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	
MAY	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151
JUN	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	
JUL	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212
AUG	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243
SEP	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
OCT	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304
NOV	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	
DEC	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365

Add 1 to unshaded values during leap years.

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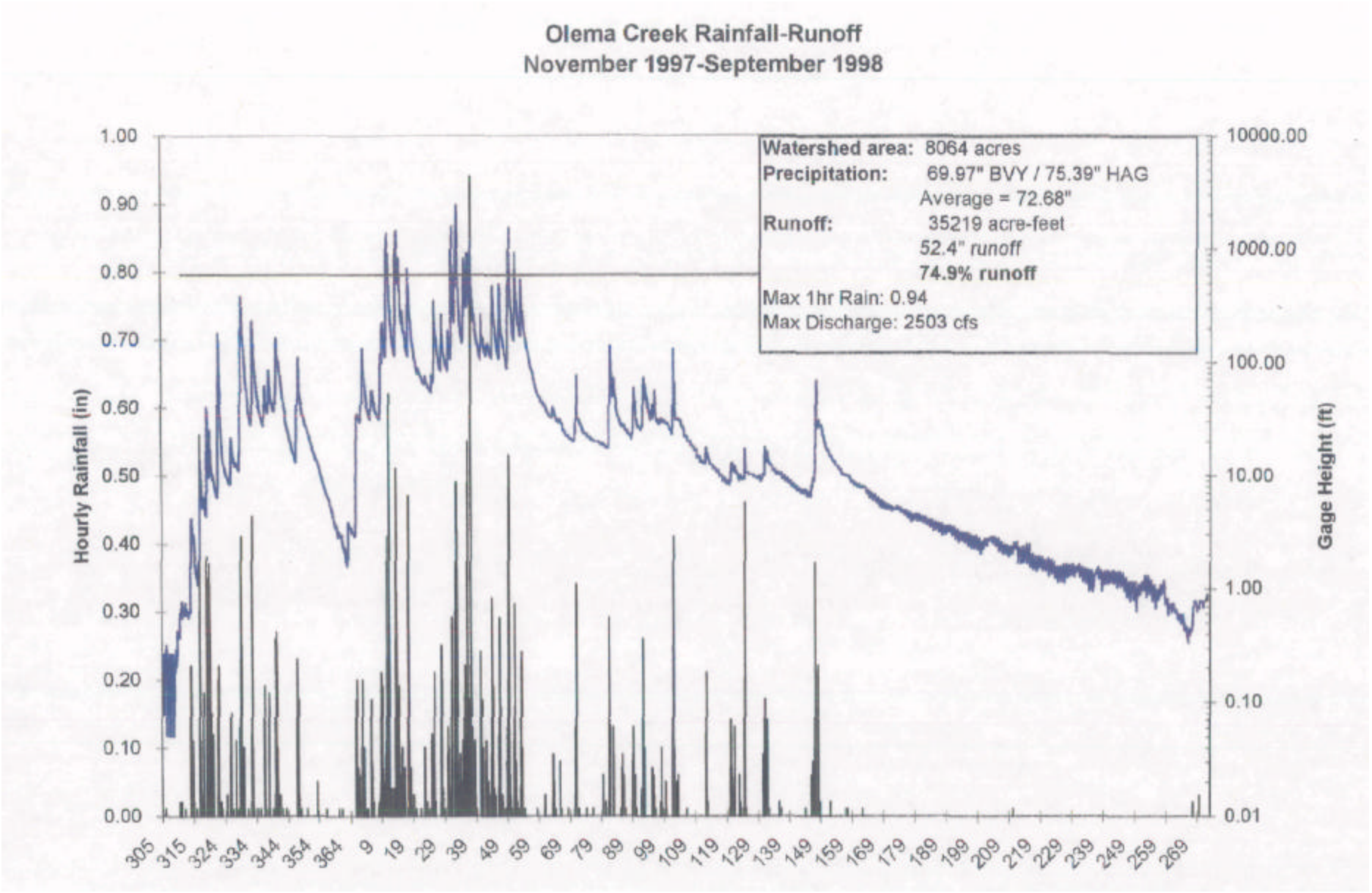
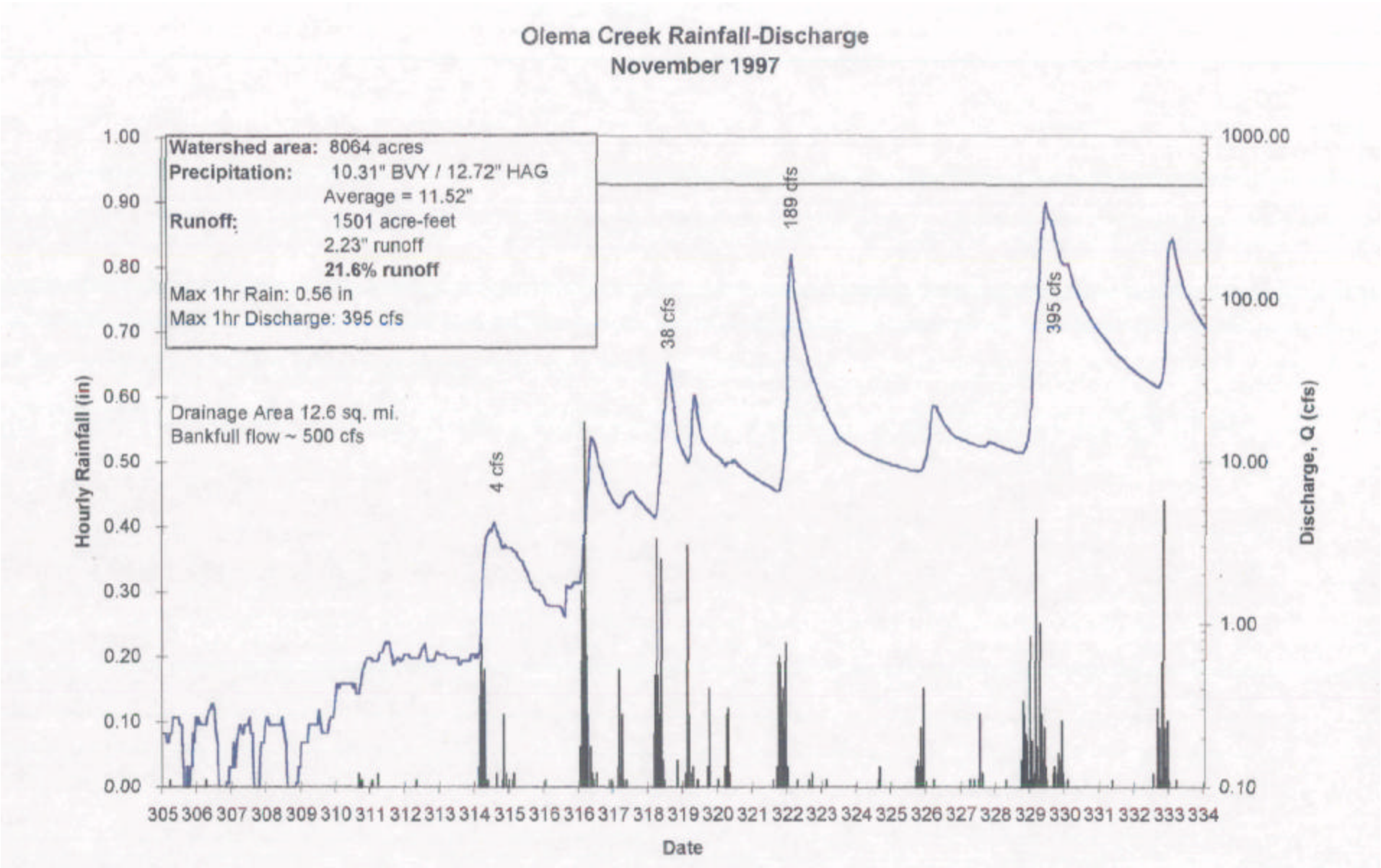
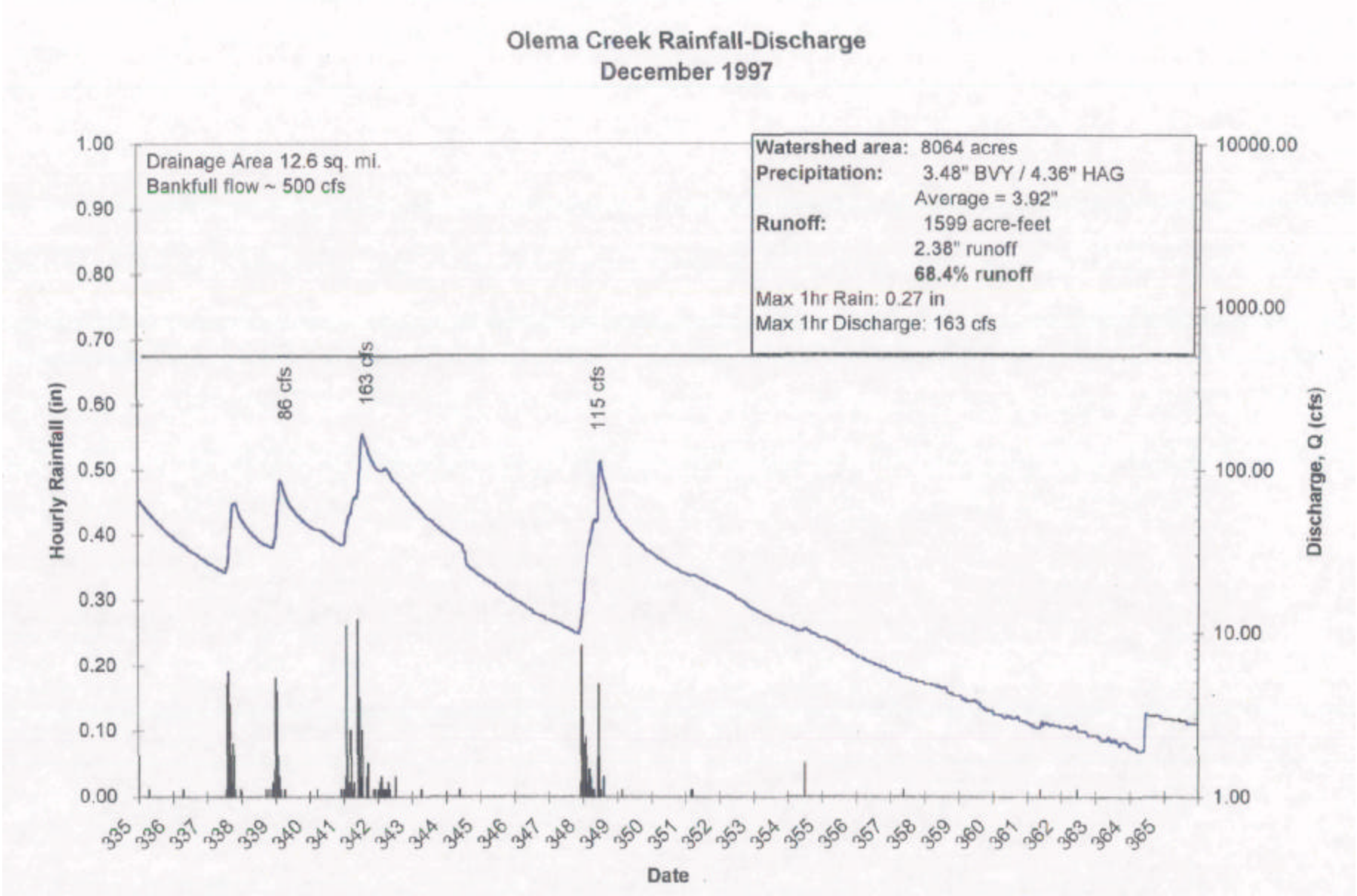
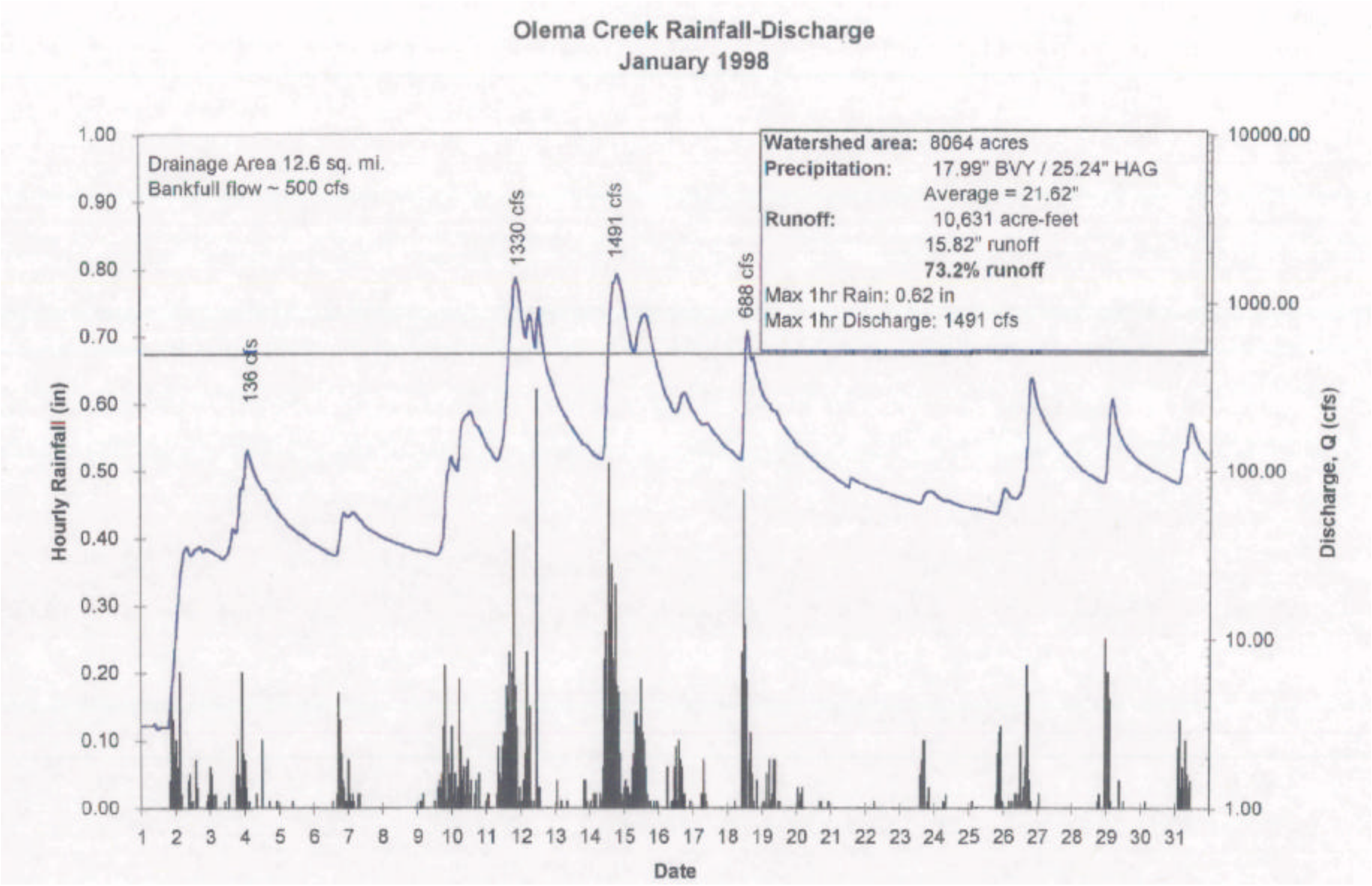
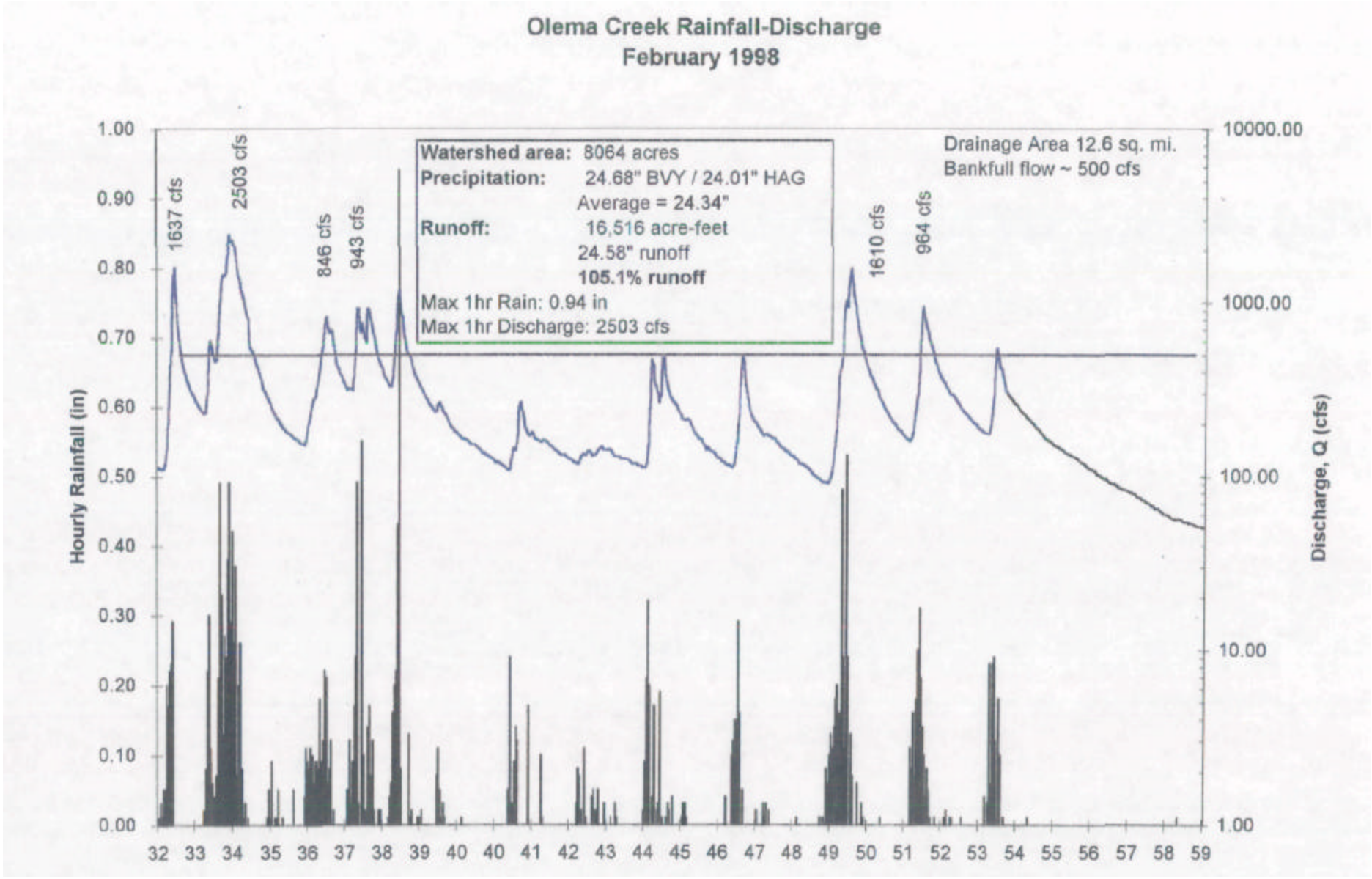
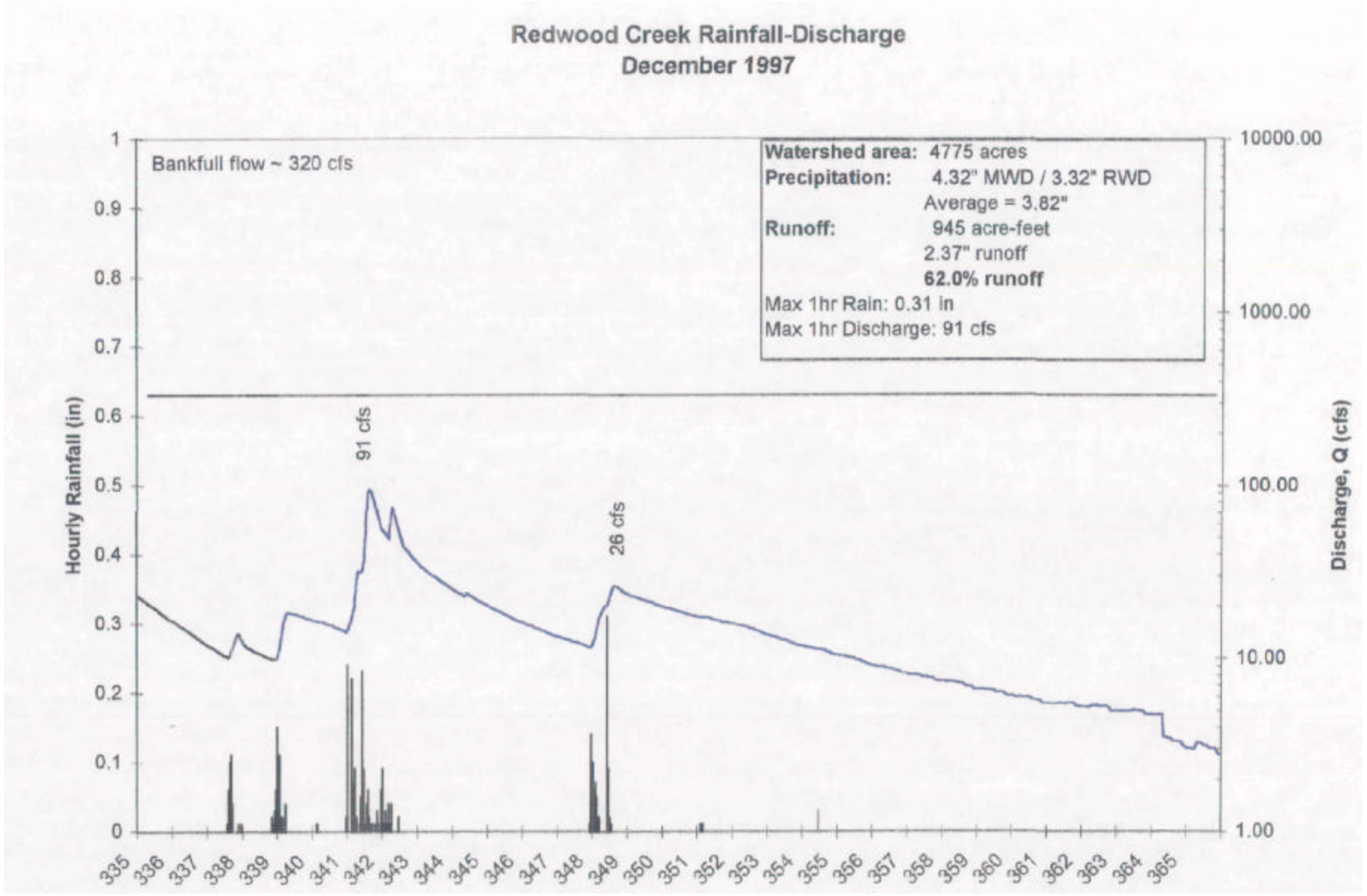

Olema Creek Rainfall-Runoff
November 1997-September 1998
Watershed area: 8064 acres
Precipitation: 69.97" BVY / 75.39" HAG
Average = 72.68"
Runoff: 35219 acre-feet
52.4" runoff
74.9% runoff
Max 1hr Rain: 0.94
Max Discharge: 2503 cfs
Hourly Rainfall (in)
Gage Height (ft)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
10000.00
1000.00
100.00
10.00
1.00
0.10
0.01
305 315 324 334 344 354 364 9 19 29 39 49 59 69 79 89 99 109 119 129 139 149 159 169 179 189 199 209 219 229 239 249 259 269

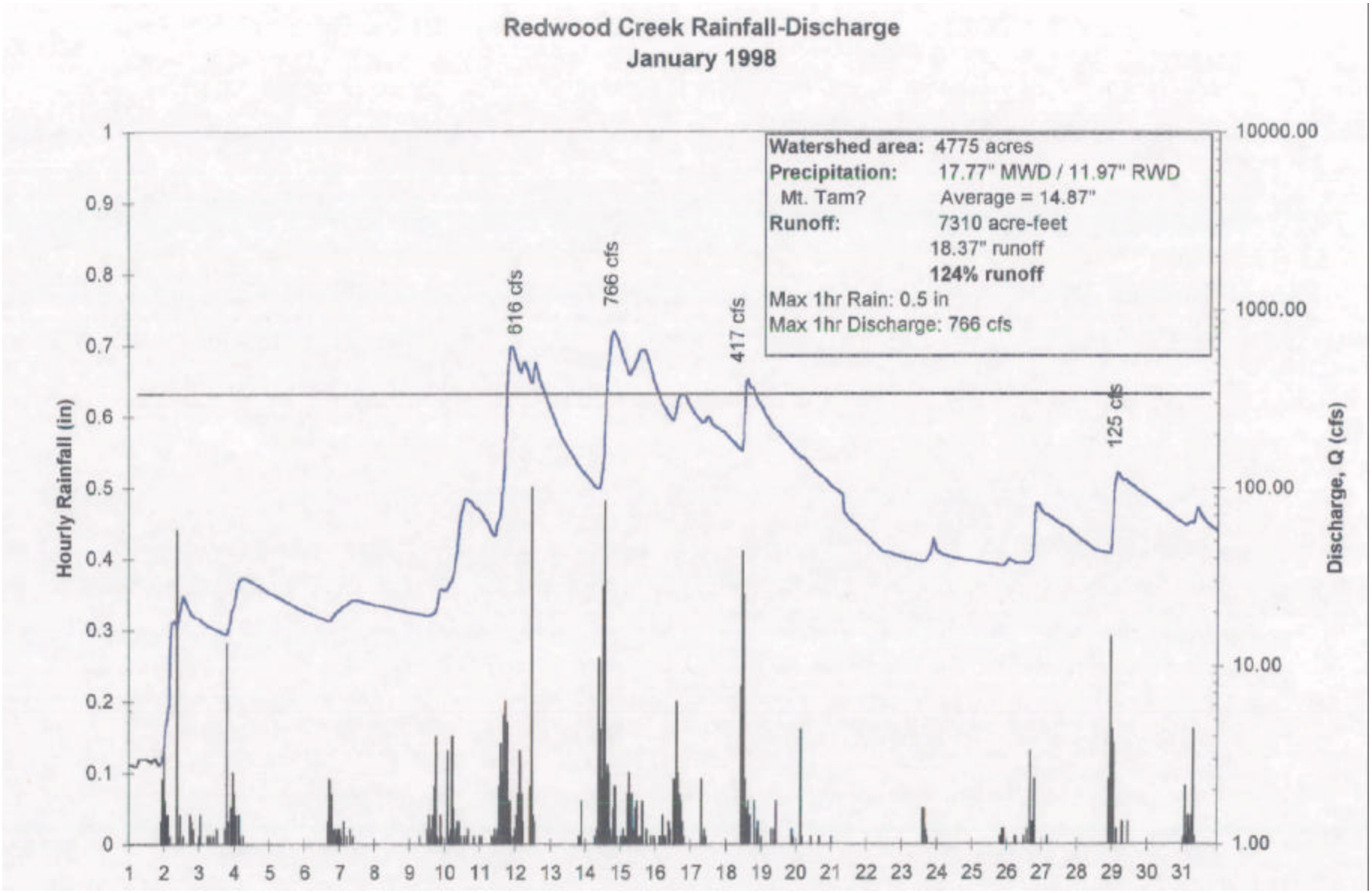

Olema Creek Rainfall-Discharge
November 1997
Watershed area: 8064 acres
Precipitation: 10.31" BVY / 12.72" HAG
Average = 11.52"
Runoff: 1501 acre-feet
2.23" runoff
21.6% runoff
Max 1hr Rain: 0.56 in
Max 1hr Discharge: 395 cfs
Drainage Area 12.6 sq. mi.
Bankfull flow ~ 500 cfs
4 cfs
38 cfs
189 cfs
395 cfs
Hourly Rainfall (in)
Discharge, Q (cfs)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1000.00
100.00
10.00
1.00
0.10
305 306 307 308 309 310 311 312 313 314 315 316 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334
Date

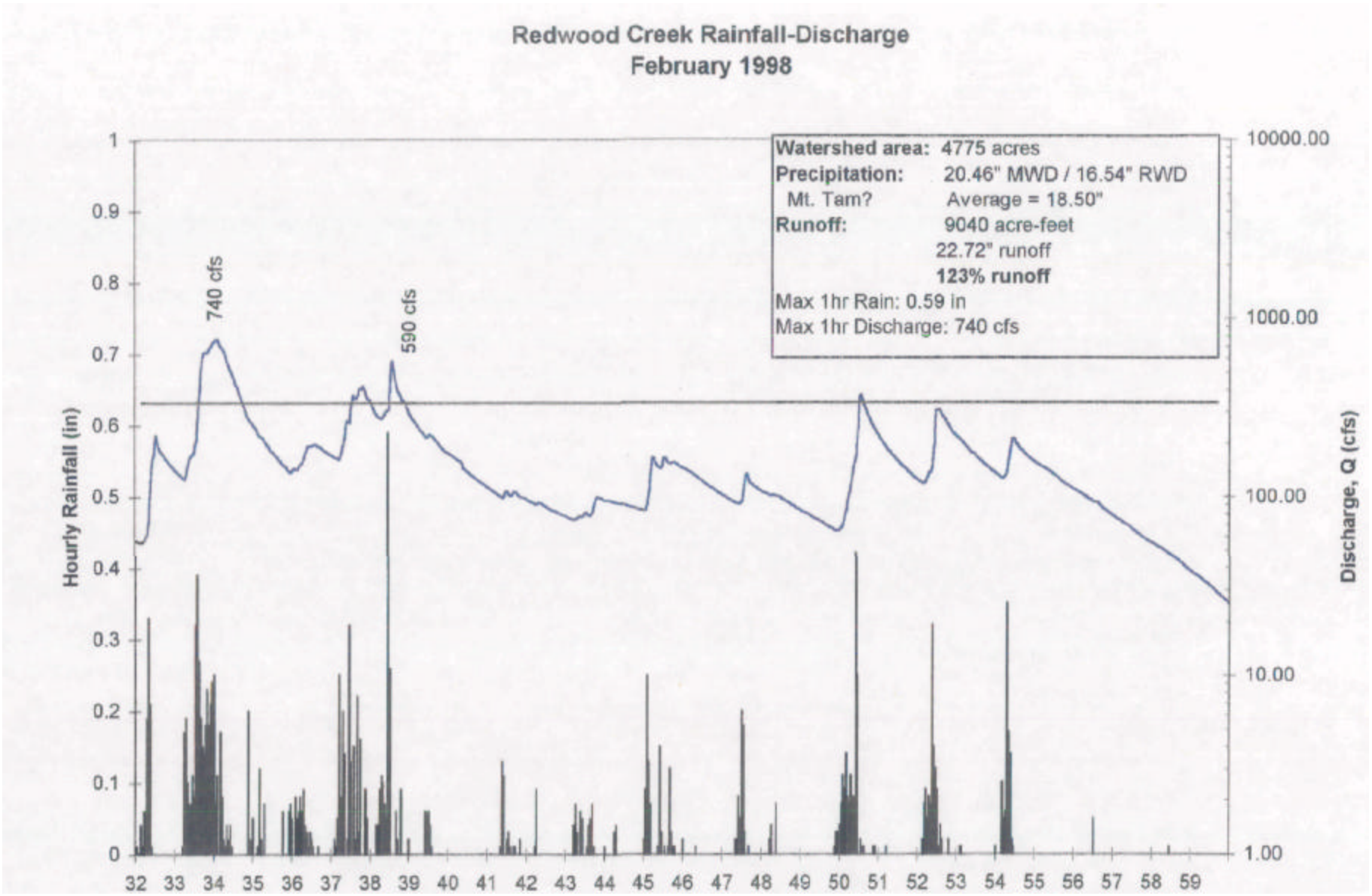

Olema Creek Rainfall-Discharge
December 1997
Drainage Area 12.6 sq. mi.
Bankfull flow ~ 500 cfs
Watershed area: 8064 acres
Precipitation: 3.48" BVY / 4.36" HAG
Average = 3.92"
Runoff: 1599 acre-feet
2.38" runoff
68.4% runoff
Max 1hr Rain: 0.27 in
Max 1hr Discharge: 163 cfs
86 cfs
163 cfs
115 cfs
Hourly Rainfall (in)
Discharge, Q (cfs)
Date


Olema Creek Rainfall-Discharge
January 1998
Drainage Area 12.6 sq. mi.
Bankfull flow ~ 500 cfs
Watershed area: 8064 acres
Precipitation: 17.99" BVY / 25.24" HAG
Average = 21.62"
Runoff: 10,631 acre-feet
15.82" runoff
73.2% runoff
Max 1hr Rain: 0.62 in
Max 1hr Discharge: 1491 cfs
136 cfs
1330 cfs
1491 cfs
688 cfs
Hourly Rainfall (in)
Discharge, Q (cfs)
Date
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
10000.00
1000.00
100.00
10.00
1.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Olema Creek Rainfall-Discharge
February 1998
Watershed area: 8064 acres
Precipitation: 24.68" BVY / 24.01" HAG
Average = 24.34"
Runoff: 16,516 acre-feet
24.58" runoff
105.1% runoff
Max 1hr Rain: 0.94 in
Max 1hr Discharge: 2503 cfs
Drainage Area 12.6 sq. mi.
Bankfull flow ~ 500 cfs
1637 cfs
2503 cfs
846 cfs
943 cfs
1610 cfs
964 cfs
Hourly Rainfall (in)
Discharge, Q (cfs)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
10000.00
1000.00
100.00
10.00
1.00
32 33 34 35 36 37 38 39 40 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59


Redwood Creek Rainfall-Discharge
December 1997
Bankfull flow ~ 320 cfs
Watershed area: 4775 acres
Precipitation: 4.32" MWD / 3.32" RWD
Average = 3.82"
Runoff: 945 acre-feet
2.37" runoff
62.0% runoff
Max 1hr Rain: 0.31 in
Max 1hr Discharge: 91 cfs
91 cfs
26 cfs
Hourly Rainfall (in)
Discharge, Q (cfs)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10000.00
1000.00
100.00
10.00
1.00
335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365


Redwood Creek Rainfall-Discharge
January 1998
Watershed area: 4775 acres
Precipitation: 17.77" MWD / 11.97" RWD
Mt. Tam? Average = 14.87"
Runoff: 7310 acre-feet
18.37" runoff
124% runoff
Max 1hr Rain: 0.5 in
Max 1hr Discharge: 766 cfs
816 cfs
766 cfs
417 cfs
125 cfs
Hourly Rainfall (in)
Discharge, Q (cfs)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.00
10.00
100.00
1000.00
10000.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Redwood Creek Rainfall-Discharge
February 1998
Watershed area: 4775 acres
Precipitation: 20.46" MWD / 16.54" RWD
Mt. Tam? Average = 18.50"
Runoff: 9040 acre-feet
22.72" runoff
123% runoff
Max 1hr Rain: 0.59 in
Max 1hr Discharge: 740 cfs
740 cfs
590 cfs
Hourly Rainfall (in)
Discharge, Q (cfs)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10000.00
1000.00
100.00
10.00
1.00
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59