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EVALUATION OF SALMON AND STEELHEAD SPAWNING HABITAT QUALITY IN THE SHASTA RIVER BASIN, 1997

by

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EVALUATION OF SALMON AND STEELHEAD SPAWNING HABITAT QUALITY IN THE SHASTA RIVER BASIN, 1997"

by

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ABSTRACT

Sediment sampling was used to evaluate chinook salmon (Oncorhynchus tshawytscha) spawning habitat quality in the Shasta River. Sediment samples were collected using a McNeil sampler and wet sieved through a series of Tyler screens (25.0 mm, 12.5 mm, 6.3 mm, 3.35 mm, 1.00 mm, and 0.85 mm); fines (particles <0.85 mm) were determined after a 10-minute settling period in Imhoff cones. Five stations were sampled in the mainstem Shasta River between RK 0.8 and 59.1. Two stations in Parks Creek were sampled at, RK 0.6 and 5.4. Spawning substrates containing 15% fines have been shown to be deleterious to egg survival; furthermore, if small sediment particles finer than 6.3 mm comprise 20-25% of spawning habitat, sac fry emergence rates decline. Fines were present in quantities at or above 15% at all but one station in the Shasta River. Station sample means for percent fines in the main stem Shasta ranged between 12.4%- 24.1%. Parks Creek station percent mean fines were found to be 28.4 and 44.3%. At all but one station, decreased sac fry emergence and reduced egg survival can be expected. The levels of fine particles were lower than those measured in 1994. Small sediments ranged between 36.2 and 73.2% for all stations; these levels have been associated with decreased sac fry emergence rates. Small sediments appear to be consistent with past Shasta River sediment investigations. These data suggest that high levels of fines and small sediment in potential salmon and steelhead spawning habitat may reduce juvenile Salmonid production from the Shasta River.

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INTRODUCTION

The Shasta River (Siskiyou County) is a major tributary in the Klamath River basin (Figure 1). The Shasta River watershed supports anadromous Pacific salmon (Oncorhynchus spp.) and steelhead (0. mykiss) populations. Runs of fall-run chinook salmon (0. tshawytscha) into the Shasta River, once numbering as high as 81,844 fish in 1931, had declined to 586 fish in 1992. Between 1991 and 1996, annual chinook salmon runs have fluctuated between 586 to 13,511 fish. Steelhead counts in the Shasta River exhibit similar declines; 8,525 fish were counted in 1932 (Snyder 1933), while 233 fish were counted in 1978 (unpublished data).

Several factors have contributed to the decline of the anadromous fishery resource in the Klamath River basin (CH2MHill 1985). They include low flows, high summer water temperatures, unscreened water diversions, degraded spawning gravels, over-appropriations of water, commercial and sport harvest, poor water quality, loss of riparian vegetation, dam-caused loss of gravel recruitment, alteration of flow regimes, overgrazing, poor ocean conditions, urbanization, road construction, disease, mining, predation, and other land management practices. Some factors have the potential to affect stream habitat quality by accelerating erosion. The resulting sedimentation can reduce the ability of a stream to produce fish in several ways. For example, I) salmon spawning habitat can be clogged or buried, reducing salmon egg survival, ii) juvenile rearing habitat could become filled, reducing the stream's carrying capacity, and iii) aquatic invertebrate production could be reduced (Reiser and Bjornn 1979).

The effects of excessive amounts of small sediment sizes on salmon and steelhead spawning gravel have been studied by several investigators (Wickett 1958, Cordone and Kelley 1961, McNeil and Ahnell 1964, Cooper 1965, Koski 1966, Bjornn 1969, Hall and Lantz 1969, Phillips et al. 1975, Cloern 1976, Tagart 1976, McCuddin 1977 , Reiser and Bjornn 1979, Tappel and Bjornn 1983). They found that high percentages of fines CO.83 mm in spawning gravel reduces water movement through the gravel bed by filling intergravel spaces, while fines overlaying spawning habitat can prevent water from entering the subgravel environment. Wickett (1958) found egg survival increased with gravel permeability. Permeability was found to be low when gravel is comprised of 15% fines (McNeil and Ahnell 1964). Incubating eggs suffer increased mortality from smothering or a build-up of metabolic wastes as a result of excessive fines. An inverse relationship exists between fines content and egg survival. Cloern (1976)

1/ As cited by Reiser and Bjornn (1979).

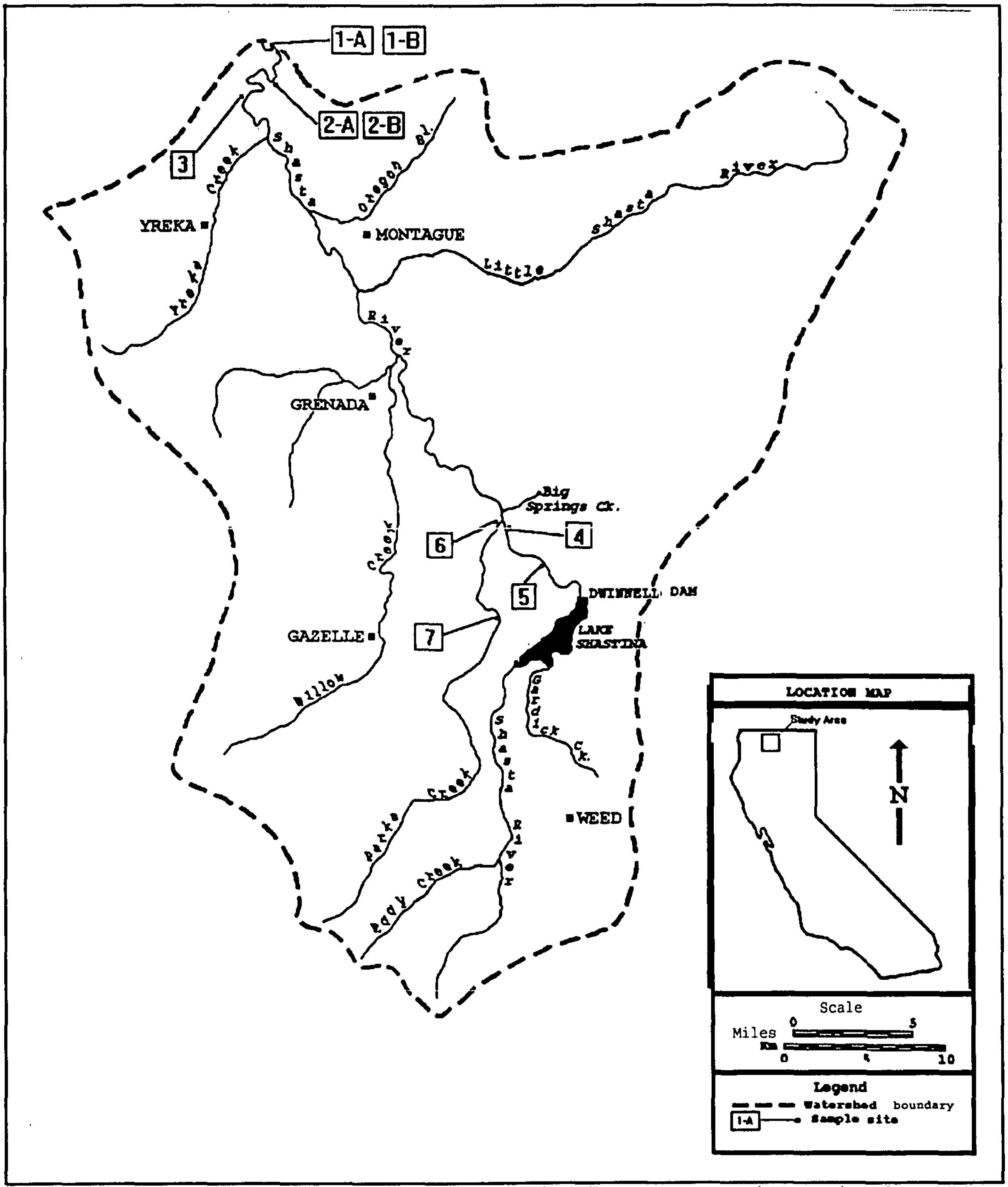

Figure 1. The Shasta River basin (Siskiyou County) depicting major landmarks. Stations are indicated where sediment samples were taken, 1997.

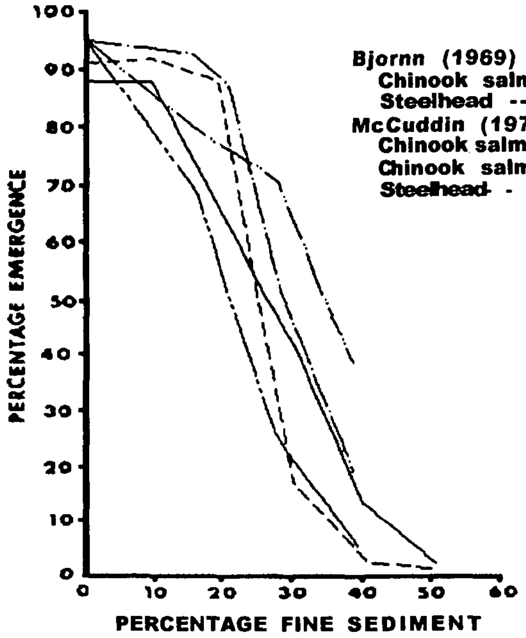

FIGURE 2. Percent emergence of fry from newly fertilized eggs in gravel-sand mixtures. Fine sediment was granitic sand with particles less than 6.4 mm. (from Reiser and Bjornn 1979)

demonstrated for coho salmon (O. kisutch) that when fines (particles <0.85 mm) exceeded 15% the proportion of eggs that hatch sharply decreased. Egg-to-emergence survival for coho salmon decreased when fines exceed 20% (Tagart 1976). Gravel comprised of 35% or more fines resulted in 0% egg-to-emergence survival for coho salmon (Koski 1966).

Sediment sizes larger than fines have also been shown to adversely affect sac fry emergence. Koski (1966) reported that emergence was inversely related to the proportion of sediment <3.3 mm in size. Hall and Lantz (1969) and Phillips et al. (1975) demonstrated that when 1-3 mm diameter sediments comprised 10-20% of the sample, steelhead and coho salmon fry emergence was reduced. Also, chinook salmon and steelhead fry emergence is reduced when 20-25% of sediment is comprised of particles <6.4 mm in diameter material (Bjornn 1969, McCuddin 1977[2]) (Figure 2).

This study evaluated chinook salmon spawning gravel quality in the Shasta River and Parks Creek.

STUDY AREA

The Shasta River basin is located in northern California and enters the Klamath River 284 river km from the Pacific Ocean. The river drains an area of about 1,554 km^2. It originates on the north slope of Mt. Eddy and flows 81 km to its mouth. River valley configuration varies considerably: small headwater streams drain onto the Shasta Valley and meander northward before dropping through a steep gradient, V-shaped canyon to the Klamath River. For purposes of discussion, the Shasta River (between the mouth and Dwinnell Dam) was divided into three reaches based on channel morphology (Table 1). Dwinnell Dam impounds Lake Shastina to provide water storage for irrigation and recreational use; it was completed in 1926 and is located at RK 64.5. The majority of the watershed is privately owned; small parcels owned by the federal government are scattered throughout the basin. The major land use is agriculture. Parks Creek flows into the Shasta at RK 55.8. The lower section of Parks Creek is a low gradient, small volume, meandering tributary. The major land use is cattle grazing, and most of the sub-basin falls on private land.

While general descriptions of spawning habitat distribution and quality in the Shasta River are available, little spawning habitat quality data is available. Wales (1951) reported that i) excellent spawning habitat was located in the lower 9.6 river km (canyon section), ii) good spawning areas existed in the 1.6 river km upstream of the canyon section, iii) Dwinnell Dam reduced available spawning habitat by 22%; the gravel near Edgewood was deemed excellent, iv) salmon and steelhead spawn in Big Springs Creek, and v) considerable, suitable spawning habitat was located below Yreka-Montague Road (RK 20.3) (the extent of this spawning habitat was not described). Coots (1957) mapped two principal chinook salmon spawning areas; a lower spawning area extended-from the mouth to approximately RK 16.1, and an upper area primarily included Big Springs Creek and portions of the Shasta River adjacent to the confluence. Coots (1962) also noted spawning in the Shasta River from the vicinity of Grenada (RK 45) to the mouth of Parks Creek (RK 55.5) and in Big Springs

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2/ As cited by Reiser and Bjornn (1979).

TABLE 1. Reach name, description, characteristic, and extent for chinook salmon spawning habitat in the Shasta River, 1997.

Reach name	Extent river km	Reach description and characteristics
		SHASTA RIVER
Lower	0 to 12.6	Mouth to Anderson Grade bridge: V-shaped canyon, steep gradient
Middle	12.7 to 53.6	Anderson Grade bridge to confluence with Big Springs Creek: wide valley floor, channel meanders, low gradient
Upper	53.7 to 64.5	Confluence with Big Springs Creek to Dwinnell Dam: numerous riffles, moderate gradient
		PARKS CREEK
Lower	0 to 22.3	Confluence with the Shasta River to the exit of steeper gradient V-shaped canyon: low gradient, meandering channel

Creek. Spawning was noted, from aerial redd counts, between the mouth of the Shasta River and Dwinnell Dam and in Big Springs Creek in the late 1970s (Rogers 1978, 1979). Detailed locations of redds were not given. However, in 1975 and 1983, no spawning was observed in the Shasta River from confluence with Big Springs Creek to Dwinnell Dam. Spawning was observed in the Shasta River between the mouth of the Shasta River to the confluence with Big Springs Creek and in Big Springs Creek (Rogers 1975, 1983). West et al. (1990) surveyed the Shasta River from the Klamath River to the confluence with Oregon Slough (RK 18.7) in 1988. They reported that this section is heavily used for spawning.

More recently, California Department of Fish and Game (CDFG) personnel conducted chinook salmon spawner surveys in the Shasta River in 1993 and 1994. These surveys recovered tags to estimate adult escapement and mapped spawning distribution. Surveys were conducted weekly during the fall-run chinook salmon spawning season between Grenada Irrigation District (GID) property (approx. RK 48) and the Klamath River (Figure 3). The heaviest chinook salmon spawning occurred in the lower 14 km of the Shasta River; spawning was observed at RK 53.8 (Louie Road bridge), 0.2 river km upstream of the confluence with Big Springs Creek (B.

Chesney, CDFG, pers. comm.). In 1995, chinook salmon spawning was observed during late October and early November in the Shasta River near RK 60, and in the lower 8 river km of Parks Creek (B. Chesney, CDFG, pers. comm.).

The first spawning habitat quality evaluation was conducted during 1980 in the lower section of the Shasta River, between RK 1.4 and 11.7, by California Department of Water Resources (CDWR)(Scott and Buer 1981). They used a core sampler to collect **a** 35.5 cm diameter x 20.3 cm deep sample at ten stations. The gravel quality varied widely. Overall the mean composition was 21% for sediment finer than 4.75 mm. This composition has been associated with reduced fry emergence (Bjornn 1969). Percent sediment particles <4.75 mm was ≥ 20% at four of the ten stations, and 18% at seven of the ten stations. The high for the ten stations was 43.5%. However, these data indicated that sediment bracketing the 0.85 mm size class are generally low. The overall means for sediment X1.18 and CO.60 mm were 9.4% and 6.2%, respectively.

West et al. (1990) visually evaluated quality of nine habitat types in the Shasta River between the mouth and Oregon Slough (Figure 1). Five of nine habitat types evaluated contained significant amounts of spawning habitat. Spawning habitat contained fines ranging from 14-52%; percent fines exceeded 15% in four of the five habitat types.

Jong (1997) evaluated chinook salmon spawning habitat in the Shasta River in 1994, using a McNeil-type sampler. Measured quantities of fine and small sediments exceeded levels found to be detrimental to egg survival and fry emergence. In the lower reach (mouth to RK 12.6(, small sediment (< 4.75 mm) and fines (<0.85 mm) were 50.7% and 34.8%, respectively. Similar levels were measured in the upper reach (RK 53.7 to 64.5) of the Shasta River; small sediments and fines were 52.6% and 31.9%, respectively.

METHODS AND MATERIALS

Replicate samples were taken for comparison, from the same potential spawning areas in the main stem Shasta River as sampled in 1994. Unlike previous investigations, (Jong 1997) exact redd locations were not mapped the previous year for follow up sediment sampling. Fewer stations were sampled in 1997 than were sampled in 1994 (Jong 1997); notably no stations were sampled in the middle reach in 1997 (Table 2).

Sampling stations in Parks Creek (RK 0.6 and 5.4) were chosen by visual inspection at a riffle crest within the thalweg in areas that were accessible to spawning salmon or harbored spawning salmon in prior years.

At each station, the potential spawning habitat was partitioned into 2 ft x 2 ft cells using a grid system. The cells to be sampled were chosen by random number generation. Twenty samples were taken from Stations 1 and 2: ten before (A) and ten after (B) (Table 2) a pulse flow was released from Dwinnell Dam on May 13 and 14, 1997. Five replicate samples were collected from all stations in the upper reach of the Shasta River. Five samples were also taken from each Parks Creek station.

Sediment samples were collected and analyzed by a method similar to that outlined by McNeil and Ahnell (1964) using a McNeil-type sampler. This sampler collects a 15.2 cm deep X 15.2 cm diameter sample. Samples were either immediately partitioned through

TABLE 2. Name, river kilometer index, and location of sampling stations in the Shasta, 1997.

Sta. name	River km	Station description
		SHASTA RIVER
Lower Reach		
1-A	0.8	100 m downstream USGS gaging station. Pre-flushing flow.
1-B	0.8	100 m downstream USGS gaging station. Post-flushing flow.
2-A	4.3	Tire flat improvement site immediately upstream of mid-stream island, 0.6 km downstream of Pioneer bridge. Pre-flushing flow.
2-B	4.3	Tire flat improvement site, 0.6 km downstream of Pioneer bridge. Station located immediately upstream of mid-channel bar. Post-flushing flow.
3	9.2	Salmon Heaven Improvement Site. Station located in center channel braid at upstream site boundary. This center channel was not present in 1994; it was likely formed by high water during the winter of 1996-97.
Upper Reach		
4	56.6	Hole in the Ground Ranch, 2.2 river km above mouth of Parks Creek.
5	59.1	Seldom Seen Ranch, 5.5 river km below Dwinnell Dam. Station located approx 100 m above wooden bridge, adjacent to larger of two springs.
		PARKS CREEK
6	0.6	Hole in the Ground Ranch.
7	5.4	Hole in the Ground Ranch.

25.0, 12.5, 6.3, 3.35, 1.0, and 0.85 mm sieves or placed in sealed buckets for partitioning at a later date. Sediment retained by each sieve was quantified by volumetric displacement. The volume of any material <0.85 mm diameter was determined after a lo-minute settling period in Imhoff cones.

In this report, all sediment particles that passed through a 6.3 mm sieve (sum of the particles retained by 3.35, 1.00, 0.85 mm sieves and fines) will be referred to as small sediment, and those passing through a 0.85 mm sieve will be referred to as fines (particles <0.85 mm).

RK data for the Shasta River were available from two sources: Scott and Buer (1981), and Pacific Southwest Inter-agency Committee (1973). Discrepancies were found between those publications. All RK data used in this report are consistent with the former publication. RK data for Parks Creek was obtained from USGS quadrangle maps using a map measurer.

RESULTS AND DISCUSSION

General Spawning Habitat Conditions

Salmon and steelhead spawning gravel if comprised of 15% or higher fines is detrimental to egg survival and fry emergence (Koski 1966, Hall and Lantz 1969, Phillips et al. 1975, Cloern 1976). The level of finesmeasured during this study at all stations, except Station 2-A, equaled or exceeded 15% (Table 3, Figure 3).

Fines measured in this study compare directly with those reported by Jong (1997). Mean fines found in the lower reach of the Shasta were lower in 1997 (16.2%) than in 1994 (34.8%). The upper reach of the Shasta showed a similar decline in percent fines, with a lower mean in 1997(19.6%) than was found in 1994 (31.9%). Differences between percent fines found at all replicate stations of 1994 and 1997 were evaluated with t-tests. All stations showed a significant difference in fines ($P \leq .05$).

Observed reductions in mean percent fines from 1994 to 1997 may be due to the high, flood volume flows in the winter of 1996-97. McNeil and Ahnell (1964) found a similar decrease in fines (co.833 mm) in Alaska's Harris River after a high flow.

Mixtures of small gravel/sand (particles <6.40 mm) can entomb chinook salmon and steelhead sac fry, preventing emergence (Bjornn 1969, McCuddin 1977[3], Tappel and Bjornn 1983). As the percent of small sediment increases to about 20-25%, percent

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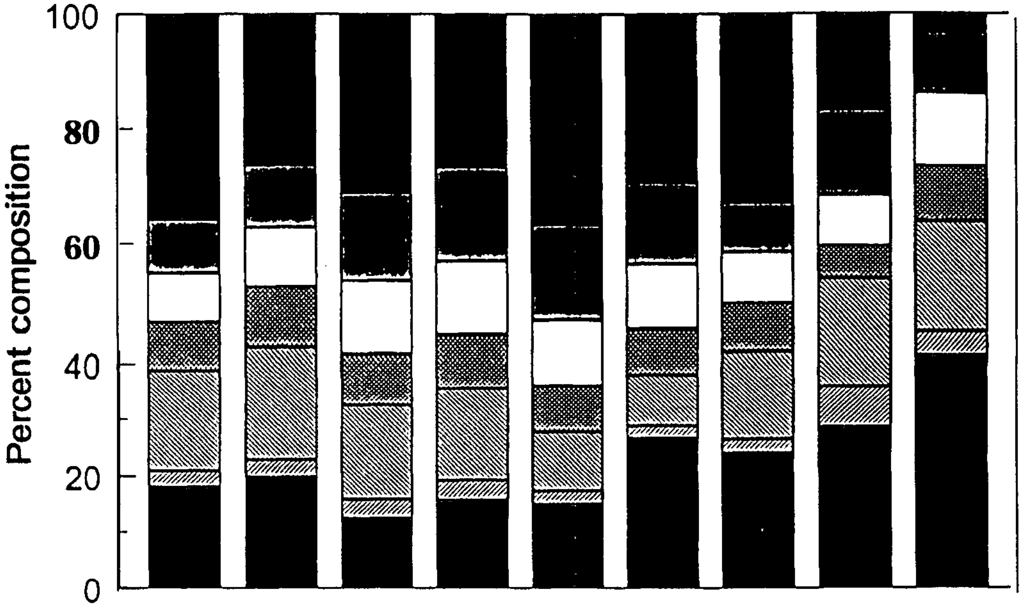
[3] As cited by Reiser and Bjornn (1979).



Station	1-A	1-B	2-A	2-B	3	4	5	6	7
Fines ■	18.0	19.9	12.4	15.7	15.0	26.6	24.1	28.6	41.3
> 0.85 mm ▨	3.0	3.0	3.4	3.6	2.3	2.2	2.4	7.4	3.8
> 1.0 mm ▧	17.9	19.8	16.8	16.4	10.4	9.4	15.5	17.9	18.6
> 3.35 mm ▩	7.7	9.9	9.1	9.1	8.5	7.5	7.8	5.6	9.5
> 6.3 mm □	8.3	10.2	11.9	12.2	10.8	10.7	8.7	8.8	12.8
>12.5 mm ▣	9.4	10.9	15.3	16.3	16.3	14.2	8.6	14.8	10.7
>25.0 mm ■	35.7	26.3	31.1	26.7	36.8	29.4	32.9	16.8	3.3
REACH	Shasta River							Parks Creek	
	Lower					Upper			

Figure 3. Station mean percent composition of particle sizes for potential Salmonid spawning habitat in the Shasta River and Parks Creek, 1997.

emergence declines rapidly (Figure 2). Small sediments measured in 1997 in the Shasta River ranged from 36.2% to 52.6% in the lower reach, and 45.2% and 49.8% in the upper reach, and 58.9% and 73.2% in Parks Creek. It is clear that small sediment particles <6.3 mm make up a large proportion of the chinook salmon spawning habitat sampled, and that these smaller materials are present in quantities associated with excessive salmon and steelhead egg mortality and decreased emergence.

TABLE 3. Potential anadromous Salmonid spawning habitat quality measured in the Shasta River 1994 and 1997. Values are reported as station mean percentages.

	Year		
	1997	1997	1994
Station 1/	Small sediment	Fines	Fines
SHASTA RIVER			
Lower Reach			
1-A	46.6	18.0	32.7
1-B	52.6	19.9	
2-A	41.7	12.4	48.2
2-B	44.8	15.7	
3	36.2	15.0	33.1
Mean	44.4	16.2	38.0
Std dev	6.1	2.9	8.8
Upper Reach			
4	45.2	15.0	41.5
5	49.8	24.1	22.3
Mean	47.5	19.6	31.9
Std dev	3.3	6.4	13.6
PARKS CREEK			
6	58.9	28.4	
7	73.2	41.3	
Mean	66.1	34.9	
Std dev	10.1	12.9	

Effects of Pulsed Flow

A small increase in flow was released from Dwinnell Dam for two days (48 hrs) starting May 14, 1997. The release was planned to study the effect of pulsed flows on the outmigration of juvenile salmon. The pulsed flow increased the volume from 3.2 m^3/sec (114 cfs) on May 13, to 4.8 m^3/sec (171 cfs) on May 14: an increase of 1.6 m^3/sec (57 cfs). The flow dropped to 4.1 m^3/sec (146 cfs) on the second day of the planned pulse flow. After the 48 hour period, the flow dropped to 2.2 m^3/sec (78 cfs) and fluctuated little until the stations were re-sampled. Stations 1 and 2 were sampled twice, once before the pulsed flow (Station 1-A, 2-A), and once after (Station 1-B, 2-B). The small sediments at Station 1 increased from 46.6% to 52.6%, with an increase in fines from 18% to 19.9%. Station 2 showed a similar increase in small sediments from 41.7% to 44.8%, and an increase in percent fines from 12.4% to 15.7%. The difference between before-pulsed-flow and after-pulsed-flow sediment content was evaluated with t-tests. There was found to be no significant difference between sample means for either station ($P > .05$).

The pulsed flow that was delivered May 13 and 14, 1997 did not change the small and fine sediment content of spawning habitat in the two stations sampled. Whether pulsed or flushing flows, in general, would be a useful tool to remove small and fine sediment from the Shasta River's spawning habitat would have to be determined by an extensive study.

CONCLUSION

It is clear that fines and small sediment particles make up a large portion of the potential anadromous Salmonid spawning habitat sampled in the Shasta River basin in 1997, and that these smaller materials are present in quantities associated with excessive salmon and steelhead egg mortality and decreased emergence. Such reductions are likely to lead to reduction of juvenile Salmonid production from the Shasta River basin. Based on the limited data collected, the quality of the Salmonid spawning habitat has improved slightly at the stations sampled since 1994, but continues to be poor.

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