State of California | The Resources Agency

Memorandum

Date: May 30, 1995

To : Files (SEDIMENT)

From : **Department of Fish and Game**
Natural Stocks Assessment Project - Bill Jong

Subject: Results of McNeil Sediment Sampling, Shasta River 1994

INTRODUCTION

The Shasta River basin (Siskiyou County) supports anadromous Pacific salmon (Oncorhynchus sp.) and steelhead (O. mykiss) populations (Figure 1). Runs of fall-run chinook salmon (O. tshawytscha), once numbering as high as 81,844 fish in 1931, had declined to 1,299 fish in 1993. Several factors have been identified which contribute to the decline of the anadromous fishery resource in the Shasta River basin. They include low flows, high summer water temperatures, unscreened water diversions, and degraded spawning gravels (CH2M-Hill 1985). Other factors include 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, development, road construction, disease, mining, predation, and other land management practices. Some of these factors have the potential to affect stream habitat quality by accelerating erosion. The resulting sedimentation can reduce the ability of the Shasta River to produce fish in several ways. For example, 1) salmon spawning habitat can be clogged or buried, reducing salmon egg survival, 2) juvenile rearing habitat could become filled, reducing the stream's carrying capacity, and 3) aquatic invertebrate (food) production could be reduced (Reiser and Bjornn 1979).

The purpose of this study is to evaluate salmon spawning gravel quality in the Shasta River basin. Descriptions of physical habitat in the Shasta River are important to decision makers. These data serve as a baseline from which to identify areas requiring habitat improvement, evaluate the effectiveness of habitat improvement projects, gives biologists an indication of the relative health of the stream, and enhances the ability of the California Department of Fish and Game (CDFG) to modify land management practices to prevent habitat degradation. The Shasta River Coordinated Resource Management Program (CRMP) is attempting to protect and promote the recovery of the anadromous

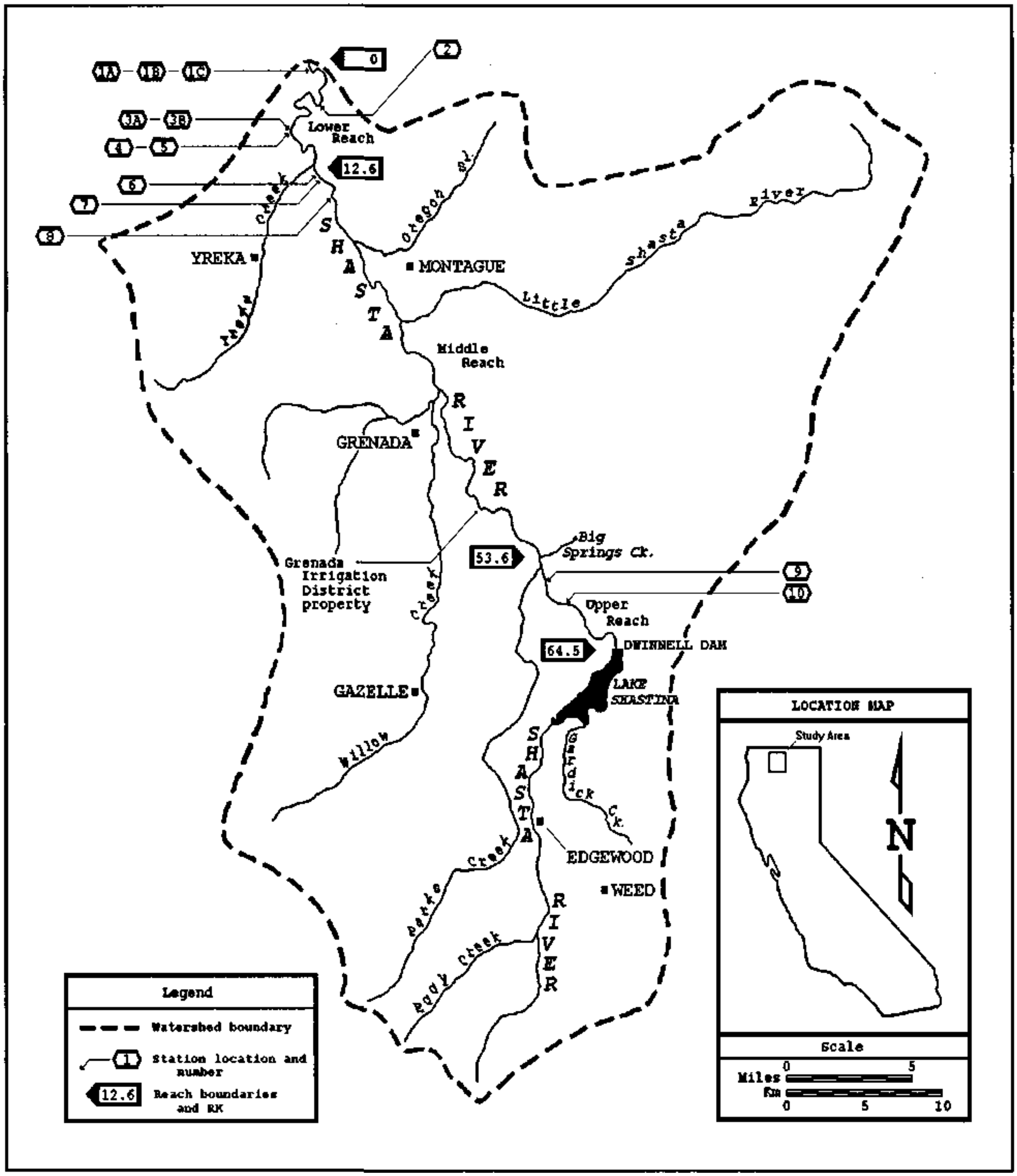


FIGURE 1. Map of the Shasta River basin (Siskiyou County) depicting the location of major landmarks and stream reaches. Also depicted are chinook salmon spawning habitat quality evaluation study sampling stations, 1994.

salmonid fishery resource in the Shasta River. Several management options exist (e.g., land acquisition, fencing, spawning gravel augmentation, gravel retention structures, ripping). However, the CRMP's limited budget requires that their activities be ranked: it is hoped that data from studies such as this will assist their efforts.

The effects of sedimentation, specifically the effects of excessive amounts of small sediment sizes on salmon and steelhead spawning gravel has been studied by several investigators (Bjornn 1969 as cited by Preston and McLeod 1990, Cloern 1976, Cooper 1965, Cordone and Kelley 1961, Hall and Lantz 1969, Koski 1966, McCuddin 1977 as cited by Reiser and Bjornn 1979, McNeil and Ahnell 1964, Phillips et al. 1975, Reiser and Bjornn 1979, Tagart 1976, Tappel and Bjornn 1983, Wickett 1958) . High percentages of fines (<0.833 mm) in spawning gravel reduces water movement through the gravelbed by filling intergravel spaces, while fines overlaying spawning habitat can prevent water from entering the subgravel environment. McNeil and Ahnell (1964) report that permeability was low when gravel is comprised of 15% fines. 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 rates. Cloern (1976) demonstrated that if percent fines (<0.85 mm) exceed 15%, coho salmon (O. kisutch) egg hatching rates rapidly decreases. Tagart (1976) reports that coho salmon egg survival to emergence decreases when fines exceed 20%. Koski (1966) reports that gravel comprised of 35% or more fines resulted in 0% coho salmon egg survival to emergence.

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 amount of sediment ≤3.3 mm. Hall and Lantz (1969) and Phillips et al. (1975) demonstrated that if 1-3 mm dia. sediments comprised 10-20% of the sample, steelhead and coho salmon fry emergence was reduced. Also, chinook and steelhead fry emergence is reduced if 20-25% of sediment is comprised of <6.4 mm dia. material (Bjornn 1969 as cited by Preston and McLeod 1990, McCuddin 1977 as cited by Reiser and Bjornn 1979) (Figure 2).

While general descriptions of the distribution of spawning habitat in the Shasta River are available, little spawning habitat quality data is available. Wales (1951) reported that 1) excellent spawning habitat was located in the lower 9.6 river km (canyon section), 2) good spawning areas existed in the 1.6 river km upstream of the canyon section, 3) Dwinnell Dam reduced available spawning habitat by 22%; the gravel near Edgewood was deemed excellent, 4) salmon and steelhead spawn in Big Springs Creek, and 5) 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 king salmon spawning areas; a lower spawning area extended from the

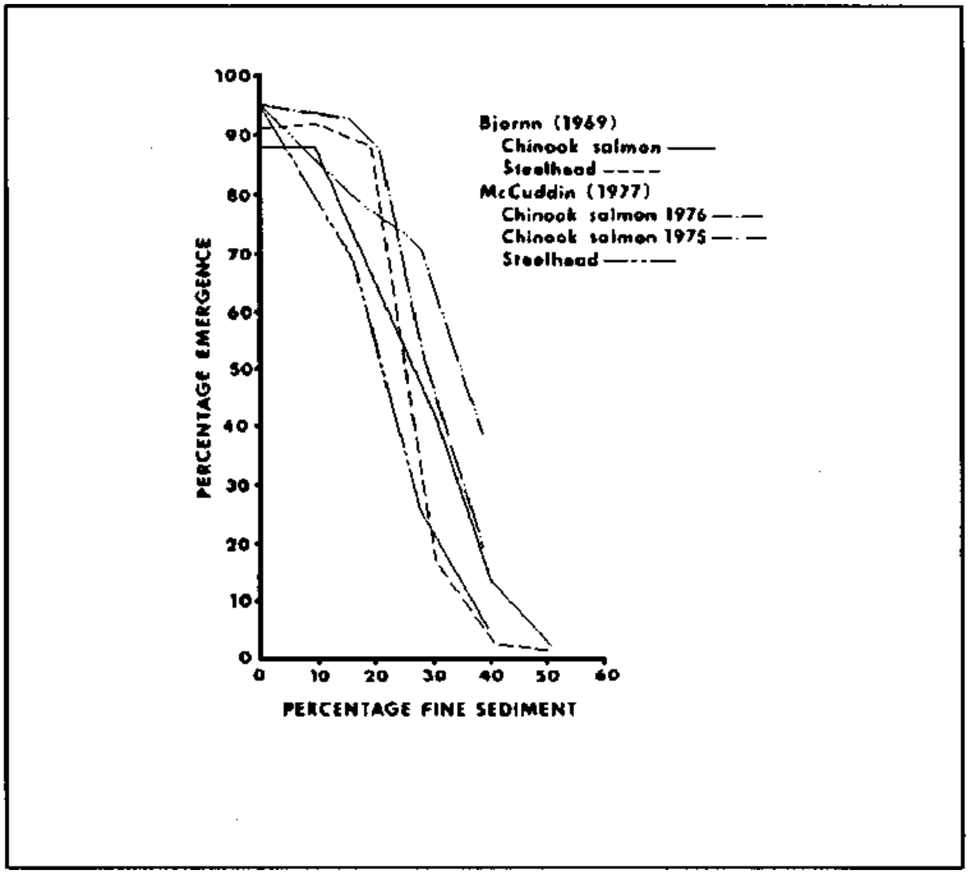


FIGURE 2. Percent emergence of fry from newly fertilized eggs in gravel-sand mixtures. Fine sediment was granitic sand with particles less than 6.4 mm. (from Reiser and Bjornn 1979)

mouth to the site of the proposed Montague Dam (approx. RK 16.1), and an upper area primarily including Big Springs Creek and portions of the Shasta River adjacent to the confluence. Coots (1962) also noted spawning activity in the Shasta River from the vicinity of Grenada (RK 45) to the mouth of Parks Creek (RK 55.5), and in Big Springs Creek. Spawning activity 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, Rogers 1979); detailed locations of redds was not discussed. 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, Rogers 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 report that this section is heavily used for spawning.

More recently, CDFG's Klamath River Project and Region 1 personnel conducted chinook salmon spawner surveys in the Shasta River in 1993 and 1994. The purpose of those surveys was to recover tags to estimate adult escapement and to map 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 1). The heaviest chinook salmon spawning occurred in the lower 14 river km (approx.) of the Shasta River; spawning activity was observed as high as RK 53.8 (Louie Road bridge), just 0.2 river km upstream of the confluence with Big Springs Creek (B. Chesney, Calif. Dept. Fish Game, pers. Comm.).

The only spawning habitat quality evaluation conducted prior to this study was conducted in the lower section of the Shasta River, between river km (RK) 1.4 and 11.7, by California Department of Water Resources personnel either in 1980 (Scott and Buer 1981). They used a core sampler to collect a 35.5 cm dia. x 20.3 cm deep sample at ten stations located between RK 1.4 and RK 11.7. Samples were partitioned through 150, 75, 37.5, 19.0, 9.5, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15, and 0.075 mm sieves. Their results are presented in Table 1. The quality of the gravel they

TABLE 1. CHINOOK SALMON SPAWNING HABITAT QUALITY DETERMINED BY CALIFORNIA DEPARTMENT OF WATER RESOURCES IN 1980 IN THE LOWER SHASTA RIVER (SCOTT AND BUER 1981)

		Percent finer [1]		
Station	RK	4.75 mm	1.18 mm	0.6 mm
LOWER REACH				
BS-3	1.4	14.5	9.5	7.5
BS-1	3.1	23.0	6.0	2.7
BS-2	4.2	19.5	10.0	7.5
BS-5	7.2	21.5	4.5	4.0
BS-6	7.2	18.0	4.2	3.0
BS-7	9.0	28.0	11.5	6.5
BS-8	9.0	18.5	8.5	6.0
BS-9	9.0	43.5	23.5	12.0
BS-10	10.8	12.0	9.7	6.8
BS-4	11.7	11.2	7.0	6.0
Mean		21.0	9.4	6.2
Std dev		9.4	5.5	2.7

[1] Bulk sample data were partitioned into an upper and lower half; these data are the mean of the two halves.

sampled was variable. Overall mean percent sediment <4.75 mm was 21.0%, which approaches quantities associated with reduced fry emergence (20-25%) for <6.4 mm by Bjornn (1969). Percent sediment <4.75 mm met or exceeded 20% at 4 of 10 stations, and 18% at 7 of 10 stations, measuring as high as 43.5% at Station BS-9 (RK 9.0). The smaller sized sieves used in 1980 do not match what typically is used to measure fines (0.85 mm): the closest sieve sizes to 0.85 mm were 1.18 and 0.6 mm, making direct comparisons difficult. However, those data do indicate that sediment bracketing the 0.85 mm size class are generally low; overall mean for sediment <1.18 and <0.6 mm was 9.4 and 6.2%, respectively. The highest measured levels of <1.18 and <0.6 mm sediment occurred at the same station where the highest level of the smallest sediment (<0.6 mm) was found: Station BS-9 (RK 9.0).

West et al (1990) visually evaluated quality of 9 habitat types in the Shasta River between the mouth and Oregon Slough (Table 2). Five of 9 habitat types evaluated contained significant amounts of spawning habitat. Percent fines ranged from 14 to 52% in those habitats; percent fines met or exceeded 18% at 4 of 5 spawning habitat types.

STUDY AREA

The Shasta River basin is located in Siskiyou County, and enters the Klamath River 284 river km from the Pacific Ocean (Figure 1) . It is approximately 64.4 river km long and drains an area of about 1,554 km^2. The headwaters rise on the east slope of China Mountain at elevation 1,658 m and it's mouth is at elevation 600 m; average gradient is 1.6%. River valley

TABLE 2. QUALITATIVE ESTIMATES OF CHINOOK SALMON SPAWNING HABITAT QUALITY DETERMINED BY U.S. FOREST SERVICE IN THE LOWER SHASTA RIVER, 1988 (WEST ET AL 1990).

Habitat	Percent					Spawn.
type	Fines	Gravel	Cobble	Boulder	Bedrock	area, m^2
Low gradient riffle	14	26	12	28	20	295
High gradient riffle	10	10	10	10	60	2
Dammed pool	60	40				3
Glide	52	28	13	6	1	164
Run	29	45	11	12	3	635
Step run	18	26	17	24	15	344
Main channel pool	35	12	6	16	31	0
Corner pool	10	20		10	60	0
Enhanced weir	20	20	30	30		1,248

configuration varies considerably: the Shasta River begins as small headwater streams, flows into a middle wide valley section, which then changes into a steep gradient, V-shaped canyon to it's confluence with the Klamath River. 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.

METHODS AND MATERIALS

Personnel of CDFG Inland Fisheries Division's Natural Stocks Assessment Project (NSAP) surveyed portions of the Shasta River, between the mouth to the GID property (approx. RK 48), to locate and map redds during the 1993 fall-run chinook salmon spawning season. Only a portion of the watershed that is available to anadromous salmonids was surveyed because of budget constraints; also, landowners who control key access points and properties were reluctant to grant access. Redds were mapped between the mouth to RK 20. Distance and compass bearing measurements from the individual redd to fixed points on shore were recorded to allow samplers to locate that redd the following summer (Jong 1993a, 1993b, 1993c, 1993d, 1993e, 1993f). During August 1994 NSAP personnel returned to the Shasta River and collected sediment samples from 11 redds (Stations 1 through 8) located between river km (RK) 0.8 and 14.8 (Figure 1, Table 3). Two additional stations (9 and 10) were sampled at RK 56.6 and 59.1 when landowner access was granted to property that was not surveyed in 1993. It is unknown if anadromous salmonids were able to migrate into, and utilize this reach in recent years. For the purposes of this report, these two stations describe potential spawning habitat.

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 (6 in.) deep x 15.2 cm (6 in.) dia. sample. Because most of the redds mapped were still visible, we were able to collect samples from the gravel covering the egg pit. Five replicate samples were collected from each redd. Samples were either immediately partitioned through 12.5, 4.75, 2.36, 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 less than 0.85 mm dia. was determined after a 10 minute settling period in Imhoff cones.

Samples from potential spawning habitat were collected from the riffle crest within the thalweg. The number of replicates, and sample processing was the same as described above.

TABLE 3. SHASTA RIVER CHINOOK SALMON AND POTENTIAL SPAWNING HABITAT EVALUATION STUDY SAMPLING STATION NUMBERS, LOCATIONS, AND DESCRIPTIONS, 1994.

Station	RK	Station Description [1]
LOWER REACH		
1-A	0.8	100 m downstream USGS gaging station, redd #1
1-B	0.8	100 m downstream USGS gaging station, redd #2
1-C	0.8	100 m downstream USGS gaging station, redd #3
2	4.3	Side channel, Tire Flat Improvement Site, 0.6 river km below Pioneer Bridge
3-A	9.0	Salmon Heaven Improvement Site, mid section, gravel retained by rock weir, redd #1 and 2
3-B	9.0	Salmon Heaven Improvement Site, mid section, gravel retained by rock weir, redd #3 and 4
4	9.2	Salmon Heaven Improvement Site, upper section, gravel retained by rock weir, redd #3 and 4
5	9.2	Side channel, Salmon Heaven Improvement Site, upper section
MIDDLE REACH		
6	13.6	50 m below Interstate Highway 5 bridge
7	13.9	150 m above Interstate Highway 5 bridge
8	14.8	1.1 river km above Interstate Highway 5 bridge
UPPER REACH		
9	56.6	Hole in the Ground Ranch, 2.2 river km above mouth of Parks Creek
10	59.1	Hole in the Ground Ranch, 5.5 river km below Dwinnell Dam

[1] Unless otherwise specified, samples were collected from the main channel of the Shasta River

River km (RK) data are 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. For purposes of discussion, the Shasta River was divided into three reaches based on channel morphology (Table 4).

In this report, all sediment particles that pass through a 4.75 mm sieve will be referred to as small sediment (<4.75 mm), and those passing through a 0.85 mm sieve will be referred to as fines (<0.85 mm).

TABLE 4. REACH DESCRIPTIONS, SHASTA RIVER SPAWNING GRAVEL EVALUATION STUDY, 1994.

Reach	Extent (RK)	Reach Characteristics
Lower	0 to 12.6	Mouth to Anderson Grade bridge: steep-sided canyon, numerous riffles, avg gradient steep (0.91%).
Middle	to 53.6	Anderson Grade bridge to confluence with Big Springs Creek: wide valley floor, channel meanders, avg gradient low (0.13%) .
Upper	to 64.5	Confluence with Big Springs Creek to Dwinnell Dam: numerous riffles, avg gradient moderate (0.50%).

RESULTS AND DISCUSSION

Sample mean percent fines (<0.85 mm) ranged from 20.8 to 55.0% at all stations sampled in the Shasta River in 1994 (Table 5, Figure 3, Appendix A-l). Large embedded rocks prevented collection of five replicate samples at Stations 1-A, 1-B, 1-C, and 10. Most researchers agree that salmon and steelhead spawning gravel are detrimentally impacted if they are comprised of 15% or higher fines (Koski 1966, Hall and Lantz 1969, Phillips et al. 1975, Cloern 1976). The level of fines measured during this study at all stations exceed 15%; at these levels, egg mortality due to smothering would be expected to occur at the stations sampled in the Shasta River in 1994.

Mean percent fines appear to vary by reach: the highest (36.3%) was measured in the Middle Reach, followed by 34.8% fines in the Lower Reach, and 31.9% fines in the Upper Reach (Table 5, Figure 3).

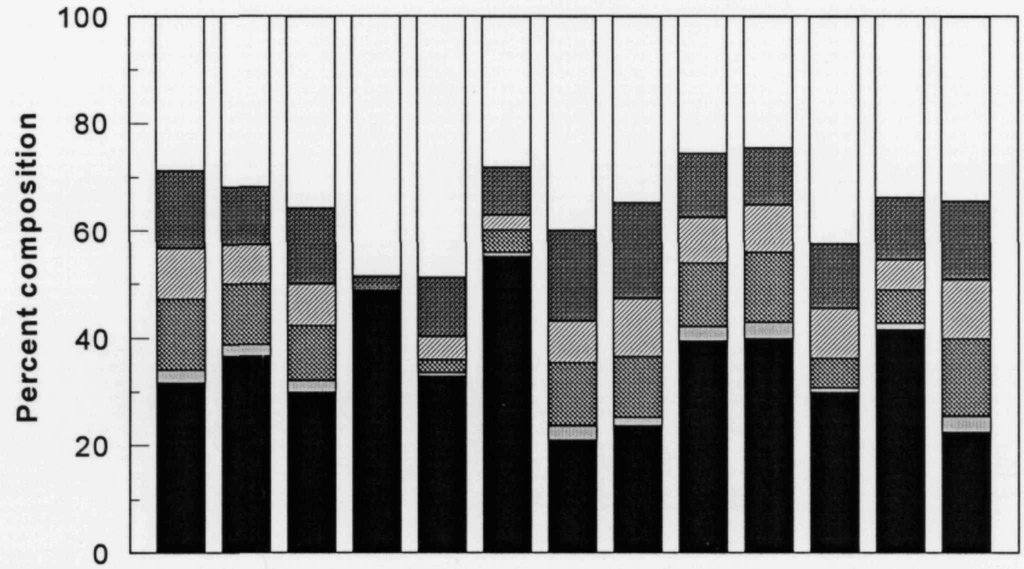
Unfortunately, percent fines measured in this study (<0.85 mm) are not directly comparable with data reported by Scott and Buer (1981); their closest sieve size to 0.85 mm was 1.18 and 0.6 mm. Also, the 10 stations bulk sampled in 1980 are located in the Lower Reach. It is obvious that fines (<0.85 mm) measured in 1994 in the Lower Reach are higher than levels of either <1.18 or <0.6 mm measured in 1980 (Tables 1 and 5, Appendix A-l). Average levels of fines measured in 1994 are 3.7x and 5.6x higher than the <1.18 and <0.6 mm 1980 Lower Reach percent levels, respectively. Also, visual estimates of percent fines in Shasta River spawning habitat surveyed by West et al (1990) in 1988 are not directly comparable to percent fines measured in this study; however,

TABLE 5. CHINOOK SALMON AND POTENTIAL SPAWNING HABITAT QUALITY MEASURED IN THE SHASTA RIVER, 1994. (SMALL SEDIMENT = ALL SEDIMENT PARTICLES PASSING THROUGH A 4.75 MM SIEVE, FINES = ALL SEDIMENT PARTICLES PASSING THROUGH A 0.85 MM SIEVE)

Station	RK	Small sediment (<4.75 mm)	Fines (<0.85 mm)
LOWER REACH			
1-A	0.8	56.6	31.6
1-B	0.8	57.3	36.6
1-C	0.8	50.1	29.8
2	4.3	48.6	48.2
3-A	9.0	40.1	32.9
3-B	9.0	62.9	55.0
4	9.2	43.1	20.8
5	9.2	47.2	23.6
Mean		50.7	34.8
Std dev		7.7	11.7
MIDDLE REACH			
6	13.6	62.4	39.3
7	13.9	64.8	39.8
8	14.8	45.5	29.8
Mean		57.6	36.3
Std dev		10.5	5.6
UPPER REACH			
9	56.6	54.4	41.5
10	59.1	50.8	22.3
Mean		52.6	31.9
Std dev		2.6	13.6
OVERALL			
Mean		52.6	34.7
Std dev		7.9	10.1

their estimates do indicate that fines are present in large quantities. These data and observations do indicate that spawning habitat quality has degraded since 1980.

Research has indicated that mixtures of small gravel/sand (<6.4 mm) can entomb chinook salmon and steelhead sac fry, preventing emergence (Bjornn 1969 as cited by Preston and McLeod 1990, McCuddin 1977 as cited by Reiser and Bjornn 1979, Tappel



STATION	1-A	1-B	1-C	2	3-A	3-B	4	5	6	7	8	9	10
<0.85 mm	31.6	36.6	29.8	48.2	32.9	55.0	20.8	23.6	39.3	39.8	29.8	41.5	22.3
>0.85 mm	2.5	2.2	2.3	0.2	0.6	0.8	2.8	1.6	2.8	3.0	0.9	1.2	3.1
>1.0 mm	13.1	11.2	10.1	0.3	2.5	4.3	11.8	11.3	11.7	13.0	5.5	6.1	14.4
>2.36 mm	9.5	7.3	7.8	0.0	4.2	2.8	7.7	10.7	8.7	9.0	9.3	5.7	11.0
>4.75 mm	14.5	10.8	14.2	2.7	10.9	8.8	16.8	17.9	11.9	10.6	12.0	11.7	14.7
>12.5 mm	28.9	32.0	35.7	48.7	49.0	28.3	40.1	34.9	25.7	24.6	42.5	33.9	34.5
REACH	Lower								Middle			Upper	

FIGURE 3. Mean percent composition of chinook salmon spawning habitat (Stations 1 through 8) and potential spawning habitat (Stations 9 and 10) sampled in the Shasta River, 1994.

and Bjornn 1983). In general, researchers have found that percent emergence ranges from 88-95% in gravel mixtures containing no small sediment. As the percent of small sediment increases to about 20-25%, percent emergence declined rapidly (Figure 2). Due to equipment limitations, this data analysis was restricted to sediment which were not retained by the 4.75 mm sieve (sum of the sediments retained by the 2.36, 1.0, 0.85 mm sieve and sediment measured after 10 min. settling time in Imhoff cones). In 1994, mean percent small sediment (<4.75 mm) was 52.6%, and ranged from 40.1 to 64.8% (Table 5, Figure 3, Appendix A-l). These data indicate that, at the stations sampled in the Shasta River in 1994, levels of small sediment exceeds levels (20-25%) that have been documented to hinder fry emergence rates.

In 1980, Scott and Buer (1981) found small sediment (<4.75 mm) exceeding the 20-25% levels associated with excessive hindrance of fry emergence (Bjornn

1969 as cited by Preston and McLeod 1990, McCuddin 1977 as cited by Reiser and Bjornn 1979) (Figure 2) in only 4 of 10 stations from the Lower Reach of the Shasta River. In 1994, measured mean levels (52.6%) were 2.5x higher that those observed in 1980 (21%), a clear indication that spawning habitat quality has degraded since 1980 (Tables 1 and 5) .

Mean percent small sediment appears to vary by reach: the highest (57.6%) was measured in the Middle Reach, followed by 52.6% small sediment in the Upper Reach, and 50.7% small sediment in the Lower Reach (Table 5, Figure 3).

It is obvious that small sediment (<4.75 mm) and fines (<0.85 mm) make up a large proportion of the spawning habitats sampled, and that these materials are present in quantities associated with excessive salmon and steelhead egg mortalities. Based on the limited data collected, the quality of the spawning habitat at the locations sampled is poor. Furthermore, levels of small and fine sediment has increased over levels measured in 1980, indicating that sedimentation of salmon spawning habitat has increased. These data indicate that spawning habitat sedimentation has the potential of reducing juvenile salmon and steelhead production from the Shasta River basin. Future restoration efforts through habitat manipulation should include reducing spawning habitat sedimentation as an objective.

RECOMMENDATIONS

1. More extensive spawning habitat quality sampling is needed to provide fishery and land managers with a full picture of conditions in the Shasta River. Future sampling should include those sites sampled in 1994; more stations should be added that are located in the areas of the Shasta River that were not surveyed nor sampled. This sampling should be conducted annually to monitor the relative health, in terms of sedimentation, of the Shasta River.

2. The use of different equipment or techniques by this study and other field and laboratory studies reviewed above makes data comparisons and trend analysis difficult. Future quantitative spawning habitat quality sampling should, as a minimum, use a series of sieves that includes 6.4 mm, 3.35 mm, 1.0 mm, and 0.85 mm. This should allow for direct comparisons with data presented in the literature.

3. A comprehensive stream survey should be conducted to identify areas contributing excessive sediment. Surveys should be conducted annually. Once these areas are located, remedial measures should be planned and implemented. Sediment

sampling could be used to identify the degree and extent of sedimentation; this information can then be used to set priorities for restoration efforts. Sediment sampling should be included in any habitat manipulations to monitor it's effectiveness.

Another benefit of this stream survey is that fishery managers would be to identify and locate migration impediments and barriers (e.g., critical riffles due to low flows, diversion dams, debris jams, culverts, and clogged fishways). Any passage problems located could then be alleviated.

4. A comprehensive sedimentation study should be planned and implemented. The purpose of this study would be to measure the effects of sedimentation on salmonid rearing habitat, aquatic invertebrate production, and spawning habitat quality. This study should examine the interactions between sedimentation, flow regimes, livestock, development, and other land management activities. Fishery and land managers would be in a better position to determine the effects of sedimentation on juvenile salmonid production in the Shasta River. Specific management recommendations to reduce the effects of sedimentation could then be formulated and implemented.

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Bill Jong
Associate Biologist (Marine/Fisheries)

cc: Barry Collins, NSA Project Leader
Mike Wallace, NSAP
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Jack West, USFS Klamath NF, Yreka

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APPENDIX A-1. PERCENT COMPOSITION FOR SIX SIZES OF SEDIMENT IN CHINOOK SALMON AND POTENTIAL SPAWNING GRAVEL SAMPLES COLLECTED AT 10 STATIONS IN THE SHASTA RIVER BASIN (SISKIYOU COUNTY), 1994.

	Sediment size, mm					
	>12.5	>4.75	>2.36	>1.00	>0.85	<0.86
Station 1-A			Date sampled :			August 30, 1994
Sample 1	28.9	14.5	9.5	13.1	2.5	31.6
Station 1-B			Date sampled :			August 30, 1994
Sample 1	28.4	11.2	7.2	10.2	1.9	41.0
Sample 2	27.6	11.1	8.5	15.1	3.1	34.5
Sample 3	39.8	10.0	6.1	8.3	1.5	34.3
Sample mean	32.0	10.8	7.3	11.2	2.2	36.6
Sample SD	6.8	0.7	1.2	3.5	0.8	3.8
Station 1-C			Date sampled :			August 30, 1994
Sample 1	39.9	15.8	7.9	10.8	2.5	23.2
Sample 2	30.9	13.9	7.9	10.4	2.0	34.9
Sample 3	38.1	15.4	8.5	8.5	1.2	28.3
Sample 4	34.1	11.6	7.1	10.9	3.5	32.8
Sample mean	35.7	14.2	7.8	10.1	2.3	29.8
Sample SD	4.0	1.9	0.6	1.1	1.0	5.2
Station 2			Date sampled :			August 31, 1994
Sample 1	37.3	4.3	0.0	0.0	0.1	58.3
Sample 2	61.1	1.0	0.0	0.2	0.2	37.6
Sample 3	46.6	0.8	0.0	0.4	0.1	52.1
Sample 4	45.7	5.6	0.0	0.2	0.1	48.4
Sample 5	52.7	2.0	0.0	0.5	0.3	44.5
Sample mean	48.7	2.7	0.0	0.3	0.2	48.2
Sample SD	8.8	2.1	0.0	0.2	0.1	7.8
Station 3-A			Date sampled :			August 9, 1994
Sample 1	48.1	17.0	5.1	4.3	0.4	25.1
Sample 2	85.8	7.6	2.2	1.6	0.5	2.2
Sample 3	34.3	7.2	3.1	3.1	0.6	51.8

APPENDIX A-1 (CONTINUED). PERCENT COMPOSITION FOR SIX SIZES OF SEDIMENT IN CHINOOK SALMON AND POTENTIAL SPAWNING GRAVEL SAMPLES COLLECTED AT 10 STATIONS IN THE SHASTA RIVER BASIN (SISKIYOU COUNTY), 1994.

	Sediment size, mm					
	>12.5	>4.75	>2.36	>1.00	>0.85	<0.86
Station 3-A (continued)			Date sampled :			August 9, 1994
Sample 4	34.6	14.3	7.5	1.0	0.8	41.9
Sample 5	42.1	8.2	3.1	2.4	0.5	43.8
Sample mean	49.0	10.9	4.2	2.5	0.6	32.9
Sample SD	21.4	4.5	2.2	1.3	0.1	19.8
Station 3-B			Date sampled :			August 9, 1994
Sample 1	18.5	10.6	4.0	4.0	0.8	61.9
Sample 2	27.9	6.8	3.9	3.4	0.9	57.1
Sample 3	41.3	14.1	2.3	2.3	0.8	39.4
Sample 4	19.5	7.7	2.2	10.7	0.9	59.0
Sample 5	34.2	4.7	1.8	1.3	0.4	57.5
Sample mean	28.3	8.8	2.8	4.3	0.8	55.0
Sample SD	9.7	3.6	1.0	3.7	0.2	8.9
Station 4			Date sampled :			August 8, 1994
Sample 1	25.3	19.6	10.6	19.9	3.5	21.2
Sample 2	48.9	17.9	6.5	10.6	2.4	13.6
Sample 3	41.9	18.2	9.7	15.3	3.8	11.0
Sample 4	43.7	16.5	6.2	6.2	1.0	26.3
Sample 5	40.5	11.6	5.6	6.9	3.4	31.9
Sample mean	40.1	16.8	7.7	11.8	2.8	20.8
Sample SD	8.8	3.1	2.3	5.8	1.1	8.7
Station 5			Date sampled :			August 8, 1994
Sample 1	43.9	15.8	9.0	8.6	1.1	21.6
Sample 2	28.5	19.9	12.6	14.6	2.0	22.5
Sample 3	43.1	19.3	10.3	10.0	1.7	15.5
Sample 4	25.1	16.6	11.2	11.4	1.6	34.1
Sample 5	33.8	18.1	10.3	11.8	1.8	24.3

APPENDIX A-L (CONTINUED). PERCENT COMPOSITION FOR SIX SIZES OF SEDIMENT IN CHINOOK SALMON AND POTENTIAL SPAWNING GRAVEL SAMPLES COLLECTED AT 10 STATIONS IN THE SHASTA RIVER BASIN (SISKIYOU COUNTY), 1994.

	Sediment size, mm					
	>12.5	>4.75	>2.36	>1.00	>0.85	<0.86
Station 5 (continued)			Date Sampled :			August 8, 1994
Sample mean	34.9	17.9	10.7	11.3	1.6	23.6
Sample SD	8.5	1.7	1.3	2.2	0.3	6.7
Station 6			Date sampled :			August 10, 1994
Sample 1	19.1	5.7	4.2	10.7	3.7	56.6
Sample 2	34.1	11.5	8.2	10.6	2.9	32.8
Sample 3	31.2	10.9	6.9	10.7	2.5	37.8
Sample 4	15.4	17.1	14.0	14.4	2.8	36.3
Sample 5	29.0	14.4	9.9	11.9	2.0	32.9
Sample mean	25.7	11.9	8.7	11.7	2.8	39.3
Sample SD	8.1	4.3	3.6	1.6	0.6	9.9
Station 7			Date sampled :			August 10, 1994
Sample 1	25.8	10.8	9.1	12.3	1.7	40.3
Sample 2	19.7	10.1	7.5	10.4	3.8	48.6
Sample 3	21.5	11.8	9.6	16.5	5.0	35.6
Sample 4	22.8	9.4	9.9	16.9	2.7	38.3
Sample 5	33.3	10.9	8.6	9.2	1.8	36.2
Sample mean	24.6	10.6	9.0	13.0	3.0	39.8
Sample SD	5.3	0.9	1.0	3.5	1.4	5.2
Station 8			Date sampled :			August 10, 1994
Sample 1	48.2	15.1	6.2	3.9	0.3	26.2
Sample 2	43.0	11.6	3.5	2.1	0.7	39.1
Sample 3	34.7	15.7	12.1	8.8	1.5	27.2
Sample 4	51.9	9.6	5.3	7.4	1.1	24.7
Sample 5	34.5	8.0	19.2	5.4	1.1	31.7
Sample mean	42.5	12.0	9.3	5.5	0.9	29.8
Sample SD	7.9	3.4	6.4	2.7	0.5	5.8

APPENDIX A-L (CONTINUED). PERCENT COMPOSITION FOR SIX SIZES OF SEDIMENT IN CHINOOK SALMON AND POTENTIAL SPAWNING GRAVEL SAMPLES COLLECTED AT 10 STATIONS IN THE SHASTA RIVER BASIN (SISKIYOU COUNTY), 1994.

	Sediment size, mm					
	>12.5	>4.75	>2.36	>1.00	>0.85	<0.86
Station 9			Date sampled :			August 11, 1994
Sample 1	39.3	13.6	6.7	6.7	1.0	32.7
Sample 2	28.8	8.4	5.9	8.0	1.6	47.3
Sample 3	32.1	7.4	3.8	3.4	0.8	52.6
Sample 4	53.2	8.9	3.8	6.0	1.3	26.8
Sample 5	16.0	20.1	8.4	6.4	1.1	48.0
Sample mean	33.9	11.7	5.7	6.1	1.2	41.5
Sample SD	13.7	5.3	2.0	1.7	0.3	11.1
Station 10			Date sampled :			August 11, 1994
Sample 1	13.6	11.5	15.9	18.6	4.8	35.6
Sample 2	42.8	17.0	9.6	12.5	2.2	15.9
Sample 3	49.5	14.9	8.1	9.1	2.3	16.2
Sample 4	32.1	15.5	10.4	17.5	3.0	21.5
Sample mean	34.5	14.7	11.0	14.4	3.1	22.3
Sample SD	15.7	2.3	3.4	4.4	1.2	9.2