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An Assessment of the Hardhead Population in Lower Willow Creek

Draft Report

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EXECUTIVE SUMMARY

In May 2000, the California Department of Fish and Game (CDFG) and the United States Forest Service (USFS) asked Pacific Gas and Electric Company (PG&E) to conduct a study to determine the current status of hardhead populations in lower Willow Creek as an element of the FERC relicensing process for the Crane Valley Project. Hardhead (*Mylopharodon conocephalus*) is a USFS sensitive species and a state species of special concern. The primary objectives of the study were to: (1) assess the biological conditions and physical/habitat conditions that affect native fish in the lower section of Willow Creek; (2) assess the current status of hardhead, a native fish considered sensitive by state and federal agencies, and (3) provide initial data for development of potential management plans that would enhance the hardhead population of Willow Creek.

Field sampling was conducted between October 3 and October 4, 2000. Rainbow trout, brown trout, Sacramento sucker, Sacramento pikeminnow, and green sunfish were collected at four sampling sites. Rainbow and brown trout were only found in the upper section of Willow Creek and in Whisky Creek. Green sunfish were only found in the upper section of Willow Creek and in Whisky Creek. Hardhead were not found at any of the four sites sampled. The absence of hardhead in the lower section of Willow Creek confirms their relative paucity in this tributary of the San Joaquin River. The absence of hardhead in this reach is not because of a lack of appropriate habitat. Lower Willow Creek appears to provide a fully functional rearing habitat for other cyprinid species. There were 227 fish collected from the 2 lower Willow Creek stations, 209 were Sacramento pikeminnow (92.1% of the total) and the remaining 18 fish were Sacramento suckers (7.9% of the total).

Sacramento pikeminnow dominate the fish assemblage in lower Willow Creek. The size distribution of Sacramento pikeminnow (almost entirely young-of-the-year and 1 year old fish) in Willow Creek illustrates its importance as a spawning/rearing habitat. It is apparent that even absent the evidence for a resident population of hardhead in lower Willow Creek, the hardhead population is not only viable but also very healthy in the Horseshoe Bend Reach of the San Joaquin River. It may be that the Horseshoe Bend population of hardhead uses lower Willow Creek for spawning and early season rearing, but absent any direct observation, our study is unable to verify any linkage between the San Joaquin River and lower Willow Creek.

A recommended management strategy is described based on study results and literature review of habitat requirements for hardhead and green sunfish. An initial minimum flow of 0.5 cfs is recommended for

Willow Creek. This minimum flow release will minimize the risk of moving large numbers of green sunfish into lower Willow Creek where they would likely prey on the juvenile hardhead during the low flow season. A 0.5 cfs minimum flow will keep the flow in Willow Creek at a level high enough to prevent stagnation, but not high enough to allow movement of the green sunfish and other introduced species into lower Willow Creek during summer low flow periods. This management strategy is designed to take advantage of the predatory nature of green sunfish to reduce their own populations during the low flow seasons.

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1.0 INTRODUCTION

This report provides current information on the fish population structure in four sampling sites located on Willow Creek and Whisky Creek which are tributaries leading to the San Joaquin River. The fish population surveys and data analysis were collected in support of collaborative efforts to relicense the Crane Valley Project (FERC 1345). The primary objectives of the surveys were to: (1) assess the biological conditions and physical/habitat conditions that affect native fish in the lower section of Willow Creek; (2) assess the current status of hardhead, a native fish considered sensitive by state and federal agencies, and (3) provide initial data for development of potential management plans that would enhance the hardhead population of Willow Creek. Field sampling was conducted between October 3 and October 4, 2000.

In May 2000, the California Department of Fish and Game (CDFG) and the United States Forest Service (USFS) and Pacific Gas and Electric Company (PG&E) decided to conduct a study to determine the current status of hardhead populations in lower Willow Creek as an element of the FERC relicensing process for the Crane Valley Project. Hardhead (*Mylopharodon conocephalus*) is a USFS sensitive species and a state species of special concern. Hardhead have historically resided in the San Joaquin River and its tributaries in the vicinity of the Crane Valley Project. Hardhead are native to California and occur in quiet sections of large, warm, clear streams with deep pools over rocky or sandy bottoms. Hardhead feed on plant and animal matter taken on or near the bottom. Hardhead are primarily bottom feeders that forage on benthic invertebrates and aquatic plant material, but they also feed on drifting organisms within the water column and on the surface. Filamentous algae are an important food for larger hardhead. Hardhead have also been reported to feed on *Carex* (Moyle 1976).

Abundance of hardhead is generally highest in pools, followed by runs, and then by riffles. Hardhead fry occupy quiet areas along the margins of streams. They reach sexual maturity after 2 years. They have a life span of 5 to 6 years. At one time, hardhead were more abundant in the lower San Joaquin river system prior to the introduction of exotic fishes like the green sunfish.

Green sunfish (*Lepomis cyanellus*) are native to the Great Lakes and the Mississippi River drainage. Green sunfish were introduced into Bass Lake, upstream of Willow Creek, and are assumed to be periodically washed downstream into Willow Creek during high flow events (Dale Mitchell, Personal Communication). Large populations of green sunfish have been observed in Willow Creek around Rex Ranch. Green sunfish are an aggressive predator of native fish with a preference for clear water pools, however they also inhabit areas of turbid water with little or no current. They typically occur in smaller streams, swamps, and ponds. The green sunfish is tolerant to a wide range of environmental conditions including adaption to a higher range of water temperatures than native fish.

Hardhead populations continue to diminish in southern San Joaquin River tributaries (Moyle, In Press). The last well-documented observations of hardhead in Willow Creek resulted from the Crane Valley Project Fisheries Technical Study conducted on streams in the Crane Valley Project area in 1984 (Bozemann et al., 1985). That study found a small population of hardhead occurring in the lower reaches of Willow Creek. The few hardhead collected at that time ranged in size from 84 to 130mm. Although not specified in the 1985 report, the population of hardhead seemed to occupy the same stream sections with green sunfish, rainbow trout (*Oncorhynchus mykiss irideus*), and brown trout (*Salmo truta*).

2.0 STUDY METHODS

A visual survey of Willow Creek from the confluence with the San Joaquin River to just above the confluence of Whisky Creek, about a 2-mile segment, was conducted on July 7, 2000. Large minnows, that could have been hardhead, were observed in pool areas along with pike minnow and Sacramento sucker. Above Whisky Creek, green sunfish were observed as well as a few catfish. Below the confluence of Whisky Creek we observed 4 to 5 inch rainbow trout. Electroshocking surveys were conducted on October 3 and 4, 2000 to quantitatively assess these same areas. Sample site selection was based on finding representative areas of each riverine reach. Sites were also selected based on geographic locations of interest such as the confluence of tributaries.

Three, approximately one hundred meter long stream stations, were sampled with backpack electrofishing equipment, using standardized methodology (Price, 1982), in selected sections of Willow Creek below the confluence of Whisky Creek (two in lower Willow Creek; and one in the Rex Ranch area). A fourth stream station was sampled in Whisky Creek a short distance above the confluence with Willow Creek. The surveys were completed prior to fall rain runoff.

A three-person crew, consisting of one member with the backpack electrofishing unit and two netters, conducted electrofishing. Prior to fish collection, block nets were placed at the lower and upper ends of each sampling site to prevent movement of fish into or out of the site during the sampling effort. The electrofishing crew usually conducted three passes through the sampling site beginning at the downstream block net. During each pass, stunned fish were netted and placed in water-filled buckets. Following each pass, all captured fish were identified to species and enumerated. Careful attention was given to the identification of small minnows. The fork lengths of each fish were measured to the nearest millimeter; the weight of each adult fish was measured to the nearest gram; and the combined weight of all juvenile fish of each species was measured to the nearest gram. The weight measurements were accomplished by using water displacement, where 1 gram of water displaced was assumed equal to 1 gram of fish. After each pass, the captured fish were released back into the stream well below the sampling site.

At each sampling site, several physical measurements and estimates were made in the stream channel to better define habitat conditions. Cover provided by overhanging plants, including shade provided by riparian vegetation, was estimated. Ten stream widths, equally spaced through the sampling site, were measured to the nearest tenth of a meter. Emergent areas in the stream were included as part of the total width measurement. Along each width measurement transect, three depths (at the quarter, half, and three-quarter points of the stream width) were measured to the nearest centimeter. If the point of depth measurement was located in an emergent area, a depth of zero was recorded.

Stream habitat classification was estimated at each sampling site using the methods described by McCain et. al. (1990).

3.0 STUDY SITES

The Willow Creek drainage is a low elevation watershed of the Sierra Nevada and is located in Madera County, California. elevations within the basin range from 366 m (1,200 ft) at the mouth to 2,286 m (7,500 ft) in the headwaters. Much of the watershed is forested by mixed oak and coniferous forests at the higher elevations, with oak savannahs in the lower elevations. Streamflows within the basin come from snowmelt and rainfall. High flows occur in the spring; flows are lowest in late summer and early fall. Rainfall begins to increase streamflows in early winter; as winter gives way to spring, melting snowpack becomes the main source of flow. The highest median flows (50% exceedence) occur between March and May, although high flow events are encountered from January to June. After June, flows decline through the summer, reach a minimum between August and October, and remain low until December.

The four study sites (Sites 1 – 4) are shown in Figure 1. Locations of the 1984 sampling are also noted in the figure.

Site 1 was located on Willow Creek upstream of the USGS gage 2465 (Latitude 38° 8' 55"(N), Longitude 119° 27' 37" (W))[1]. This site was located 200 meters above USGS gage 2465 and 300 meters above the confluence of Willow Creek with the San Joaquin River. The length of the stream section sampled was 80 meters. Elevation at the site was 1240 feet based on elevations from the USGS Quadrangle. The site had a mean width of 19.41 meters and a mean depth of 8.58 centimeters. Riparian vegetation was sparse along the stream margin and provided limited cover of fish in some areas. Total area surveyed for fish was 1.55 hectares. The substrate at this site was primarily bedrock (40%) and sand (35%). The stream section begins at a narrow riffle and extends downstream through low gradient riffles into a large pool. Habitat types were 70% pool, 25% riffle, and 5% run. The site is a difficult hike from the nearest parking area and fishing pressure is presumed to be light.

[1] All Latitude and Longitude coordinates are based on UTM and the NAD 1983 Datum.

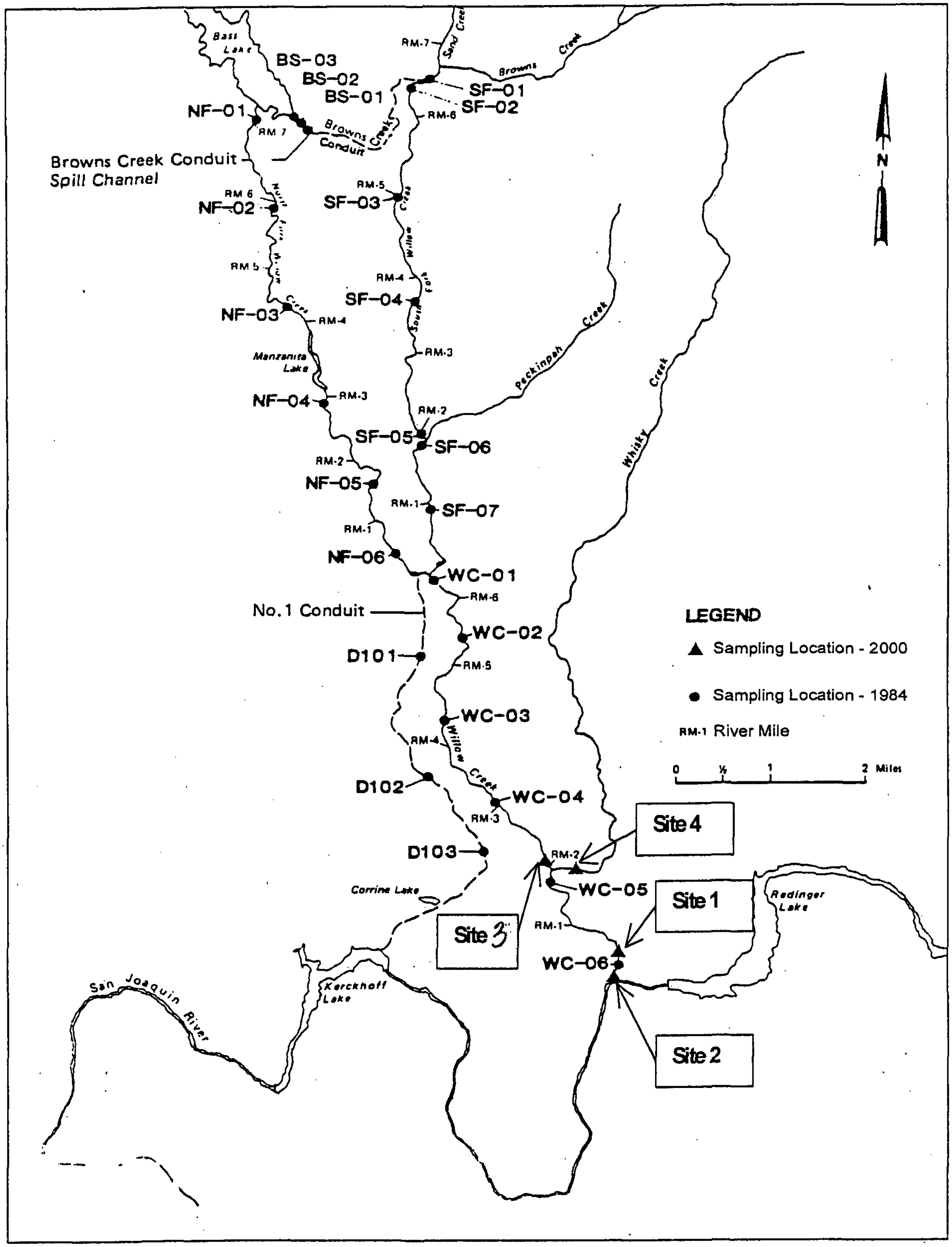


Figure 1. Sensitive fish study fish sampling locations in Willow Creek Drainage.

Site 2 was located on Willow Creek above the confluence of San Joaquin River (Latitude 37° 9' 8"(N), Longitude 119° 27' 39"(W)). This stream section was located 100 meters above the confluence of Willow Creek with the San Joaquin River. The length of the stream section sampled was 155 meters. Elevation at the site was 1180 feet based on elevations from the USGS Quadrangle. The site had a mean width of 13.39 meters and a mean depth of 5.45 centimeters. Riparian vegetation was dense along the stream margin and provided extensive cover of fish in most areas. Total area surveyed for fish was 2.08 hectares. The substrate at this site was primarily rubble (30%) and gravel (30%) with the remainder split evenly between sand and bedrock. The stream section begins at a narrow riffle and extends downstream through low gradient riffles and a few moderately deep pools spilling into a small run and finally into a large shallow pool. Habitat types were 80% pool, 10% riffle, and 10% run. The site is a difficult hike from the nearest parking area but there is a well used trail down to the confluence which suggest that fishing pressure is light to moderate.

Site 3 was located on Willow Creek above the confluence of Whisky Creek (Latitude 37° 10' 1"(N), Longitude 119° 28' 28"(W)). This site was located 100 meters above the confluence of Willow Creek with Whisky Creek. The length of the stream section sampled was 89 meters. Elevation at the site was 1680 feet based on elevations from the USGS Quadrangle. The site had a mean width of 16.92 meters and a mean depth of 4.10 centimeters. Riparian vegetation was sparse along the stream margin and provided limited cover of fish in some areas. Total area surveyed for fish was 1.51 hectares. The substrate at this site was primarily bedrock (85%) and boulder (10%) with the remainder being sand. The stream section begins at a bedrock cascade flowing into a narrow riffle and extends downstream into several deep pools linked by short runs. Habitat types were 95% pool, 3% riffle, and 2% run. The site is a difficult hike from the nearest parking area with limited trail access which suggest that fishing pressure is light.

Site 4 was located on Whisky Creek above the confluence of Willow Creek (Latitude 37° 9' 53"(N), Longitude 119° 28' 10"(W)). This station was located 100 meters above the confluence of Willow Creek. The length of the station was 117 meters. Elevation at the site was 1720 feet based on elevations from the USGS Quadrangle. The site had a mean width of 14.36 meters and a mean depth of 6.58 centimeters. Riparian vegetation was sparse to moderate along the stream margin and provided small areas of cover for fish. Total area surveyed for fish was 1.68 hectares. The substrate at this site was primarily rubble (40%), sand (20%), and gravel (20%) with the remainder being sand and bedrock. The station begins at a bedrock surrounded pool and extends downstream through low gradient riffles and a few small runs and finally into another shallow pool. Habitat types were 80% pool, 10% riffle, and 10% run. The site is a difficult hike from the nearest parking area which suggest that fishing pressure is light.

4.0 RESULTS

All data collected were entered into an Excel database. For each sampling site, the physical habitat data were summarized (Table 1). This summary included the following: length of the sampling site, mean stream width, mean stream depth, wetted surface area in hectares, wetted volume in cubic meters, and estimates of the various physical characteristics.

Fish species that occur in the study area are described in Table 2. Fish population estimates were calculated by species for each sampling site (Table 3). Population estimates with 95% confidence limits were calculated using a three-pass depletion method. Electrofishing data were analyzed using the software package MicroFish 3.0, which uses a removal-depletion model (Van Deventer and Platts, 1989). The MicroFish program calculated the maximum likelihood population estimates, capture probabilities, lengths, weights, and biomass based on fish capture data for a sample site. Fish populations were reported as the number of fish by species per 100 meters of stream and per kilometer of stream. Standing crop estimates in terms of biomass per unit of measure were calculated by species for each sampling site. Biomass included the total weight measured for each species. Standing crop estimates were calculated in kg of fish per hectare of stream surface.

Species composition (Table 4) was calculated for each sampling site and expressed as the following: 1) species composition by numbers of fish based on the population estimates for the entire sampling site; or 2) species composition by numbers of fish based on the actual catch for the sampling site. For each sampling site, a length frequency histogram was developed for each species, and the age class structure was estimated based on these histograms (Figures 2 through 10).

Table 1

Physical habitat data summary for sites 1 through 4

	Crane Valley Project Sensitive Fish Study			
	Site 1	Site 2	Site 3	Site 4
Date	10/04/00	10/04/00	10/03/00	10/03/00
Time	16:31	11:04	15:30	10:34
Air Temp	21.0	29.0	23.5	28.0
Water Temp (C)	19.5	20.5	24.0	18.0
Station Length (m)	80	155	89	117
Mean Width (m)	19.41	13.39	16.92	14.36
Mean Depth (cm)	8.58	5.45	4.10	6.58
Wetted Area (hectares)	1.55	2.08	1.51	1.68
Wetted Volume (m^3)	133.15	113.11	61.74	110.47
Estimated Flow (cfs)	1.0	1.0	0.1	1.0
Bottom Type (%)				
Clay	0	0	0	0
Silt	0	0	0	2
Sand	35	20	5	20
Gravel	3	30	0	20
Rubble	17	30	0	40
Boulder	40	20	10	15
Bedrock	5	0	85	3
Canopy (%)	10	50	2	20
Gradient (%)	3	1	2	2
Habitat Type				
Pool (%)	70	80	95	80
Riffle (%)	25	10	3	10
Run (%)	5	10	2	10
Cover Type (% of Surface Area)				
Surf Turbulence	1	0	0	1
Object Cover	10	5	15	5
Undercut Bank	0	0	0	0
Overhanging Vegetation	2	10	5	2
Spawning Habitat Rating	0	2	0	3

Table 2

Fish species occurring in the study area including lower section of Willow Creek and Whisky Creek.

Species		Native or Introduced	Habitat	Comments
Rainbow Trout	*Oncorhynchus mykiss*	Native	Low and high elevation streams	Stable in areas below Whisky Creek
Brown Trout	*Salmo trutta*	Introduced	Low and high elevation streams	Abundant in Whisky Creek
Hardhead	*Mylopharodon conocephalus*	Native	Low elevation streams with large pools	California Species of Special Concern US Forest Service Sensitive Species
Sacramento Pikeminnow	*Ptychocheilus grandis*	Native	Low elevation streams with large pools	Common below barriers
Sacramento Sucker	*Catastomus occidentalis*	Native	Low and high elevation streams	Stable below Whisky Creek
Green Sunfish	*Lepomis cyanellus*	Introduced	Moderate to low elevation streams with pools	Abundant in Bass Lake

Table 3

Fish population and standing crop estimates for each sampling site calculated by species. Population estimates with 95% confidence limits were calculated using a three-pass depletion method.

Species	Estimated Number	Mean Fish Length (centimeters)	Total Weight (grams)	Fish per 100 meters	Fish per Kilometer	Kilograms per hectare
Site 1						
Rainbow Trout						
Brown Trout						
Sucker						
Pikeminnow	141	48.81	105	176.25	1762.50	0.07
Green Sunfish						
Site 2						
Rainbow Trout						
Brown Trout						
Sucker	18	75.33	125	11.61	116.13	60.23
Pikeminnow	179	52.88	365	115.48	1154.84	0.18
Green Sunfish						
Site 3						
Rainbow Trout	4	85.3	40	4.49	729.06	0.27
Brown Trout						
Sucker	9	88.11	90	10.11	753.08	0.06
Pikeminnow						
Green Sunfish	69	39.96	105	77.53	341.54	0.07
Site 4						
Rainbow Trout	32	76.27	250	27.35	273.50	0.15
Brown Trout	30	93.96	435	25.64	256.41	0.26
Sucker	28	74.63	390	23.93	239.32	0.23
Pikeminnow						
Green Sunfish	1	92	20	0.85	8.55	0.01

= introduced species

Table 4

Species composition by species for each sampling site expressed as species composition by numbers of fish based on population and by numbers of fish based on the actual catch for each sampling site.

Species	Estimated Number	Species Composition	Actual Number	Species Composition
Site 1				
Rainbow Trout				
Brown Trout				
Sucker				
Pikeminnow	141	100.00%	57	100.00%
Green Sunfish				
Site 2				
Rainbow Trout				
Brown Trout				
Sucker	18	9.14%	18	10.71%
Pikeminnow	179	90.86%	150	89.29%
Green Sunfish				
Site 3				
Rainbow Trout	4	4.88%	4	4.88%
Brown Trout				
Sucker	9	10.98%	9	10.98%
Pikeminnow				
Green Sunfish	69	84.15%	69	84.15%
Site 4				
Rainbow Trout	32	35.16%	22	28.21%
Brown Trout	30	32.97%	28	35.90%
Sucker	28	30.77%	27	34.62%
Pikeminnow				
Green Sunfish	1	1.10%	1	1.28%

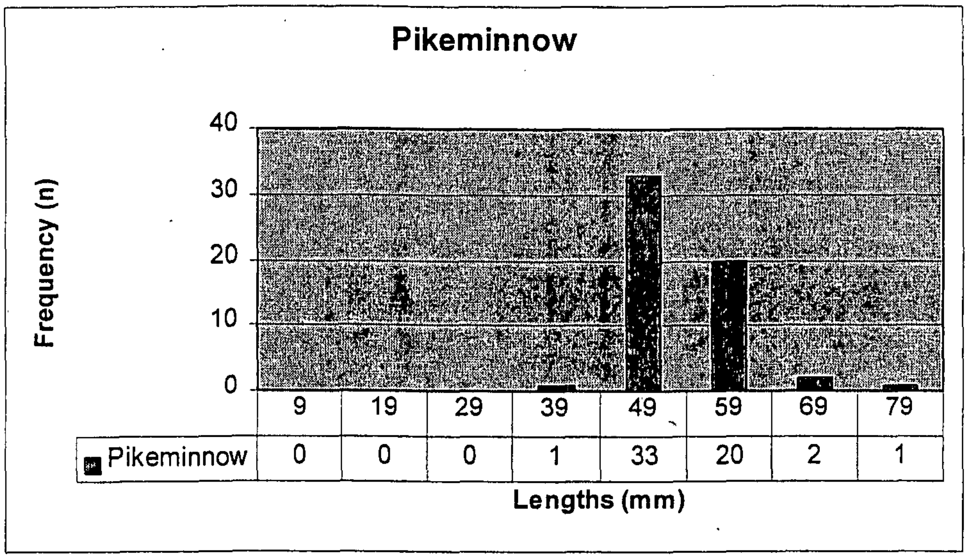


Figure 2. Length frequency of pikeminnow collected at Site 1. No other fish species were collected at this location.

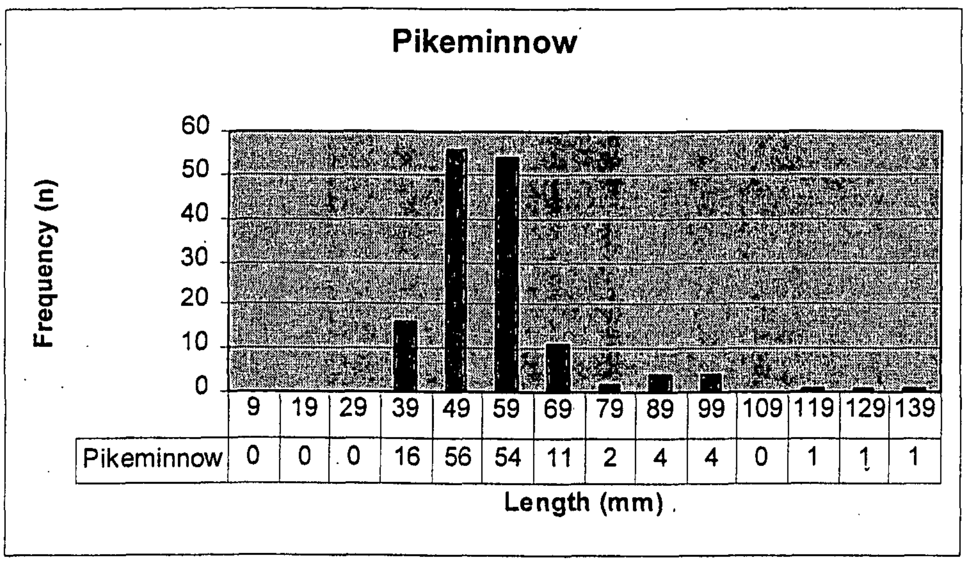


Figure 3. Length frequency of pikeminnow collected at Site 2.

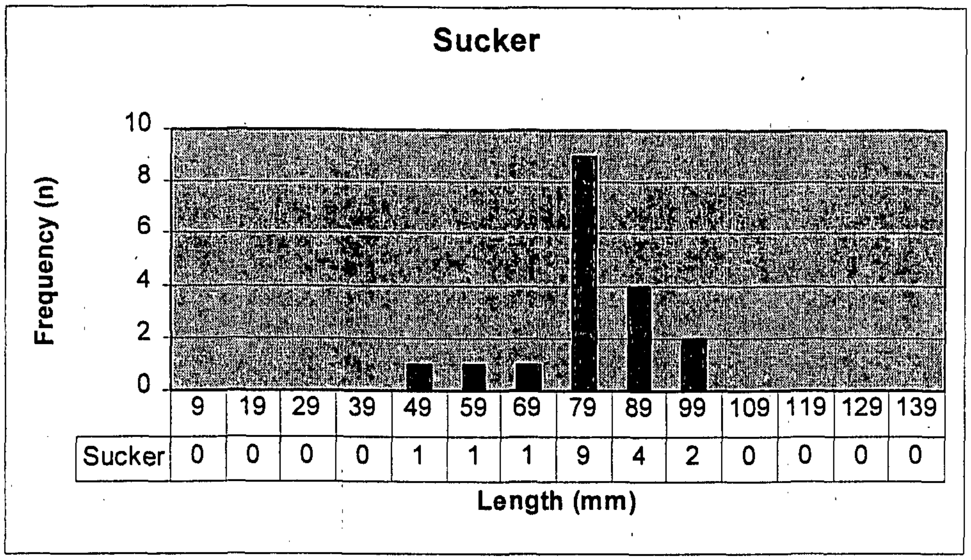


Figure 4. Length frequency of sucker collected at Site 2.

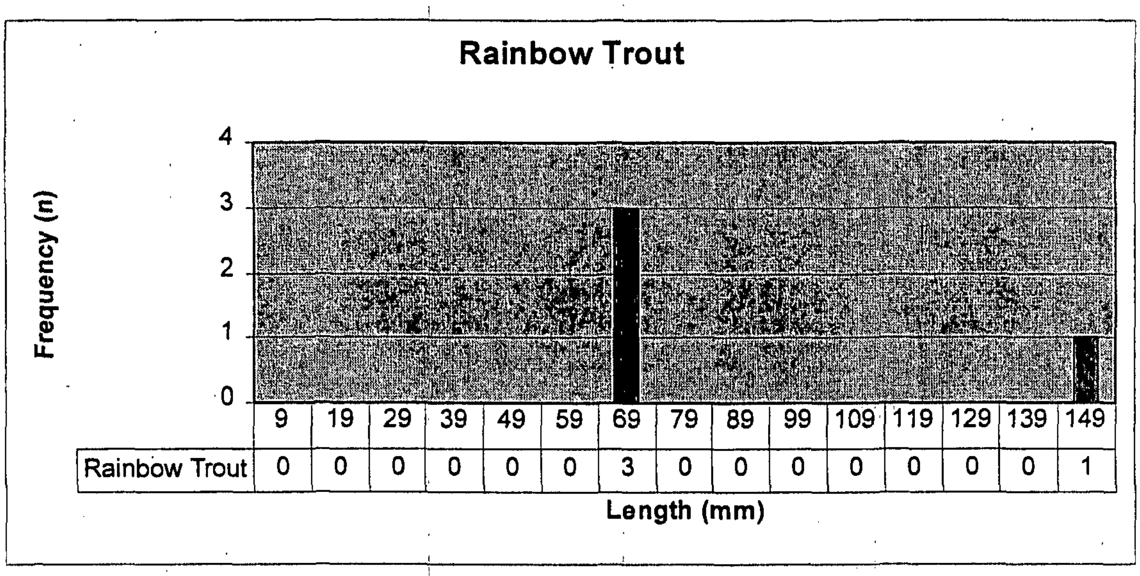


Figure 5. Length frequency of rainbow trout collected at site 3.

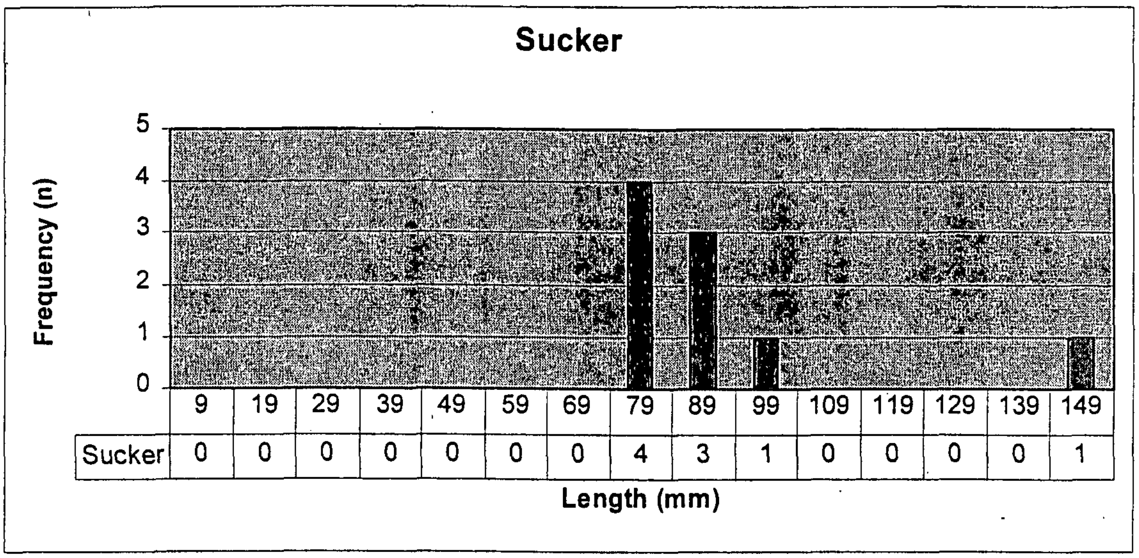


Figure 6. Length frequency of sucker collected at Site 3.

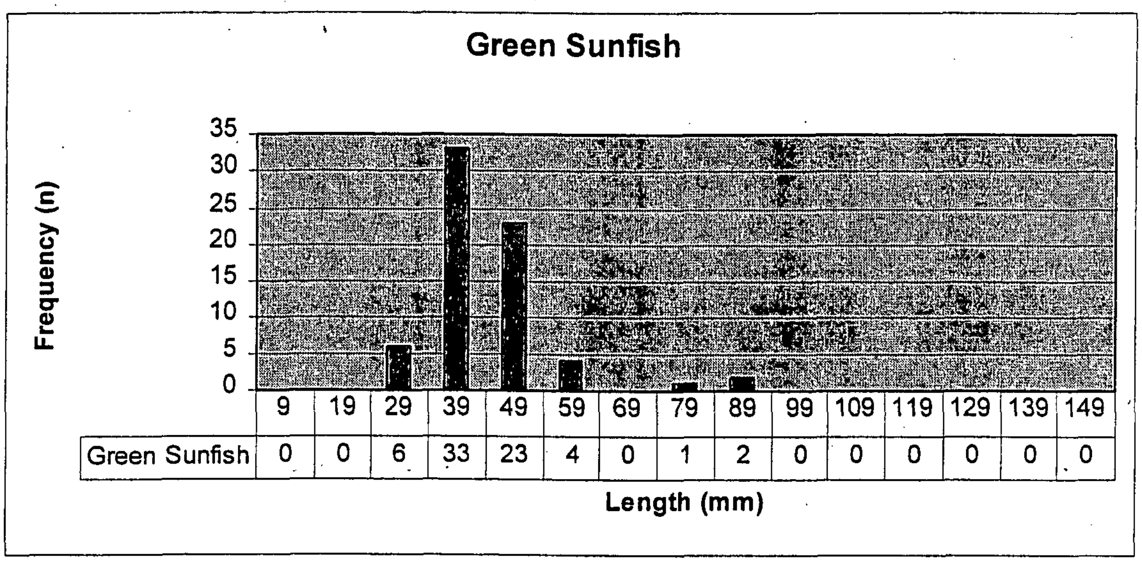
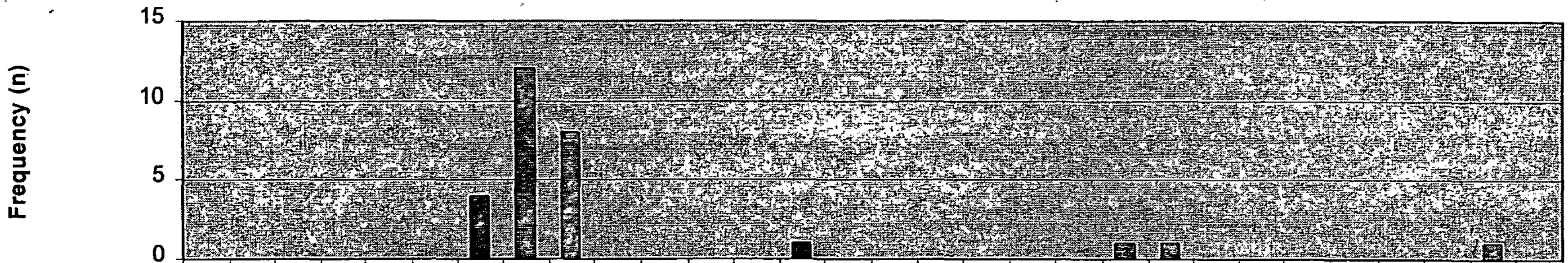


Figure 7. Length frequency of green sunfish collected at Site 3.

Brown Trout

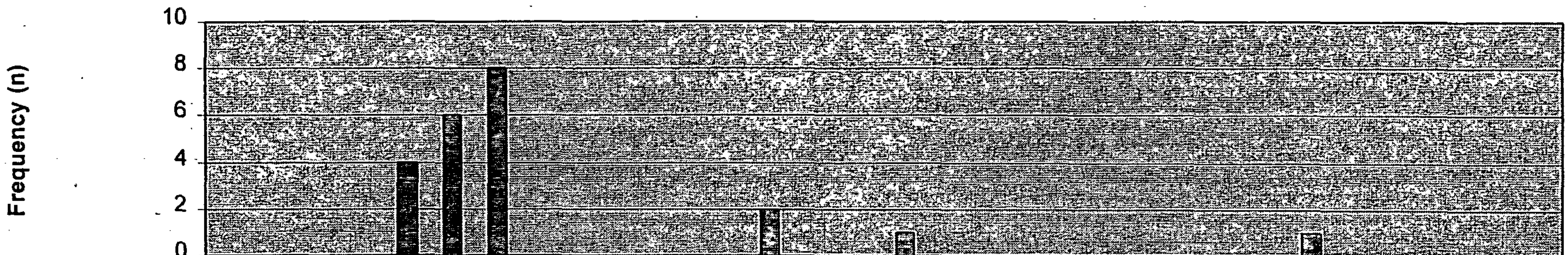


	9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199	209	219	229	239	249	259	269	279	289	299
Brown Trout	0	0	0	0	0	0	4	12	8	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0

Length (mm)

Figure 8. Length frequency of brown trout collected at site 4.

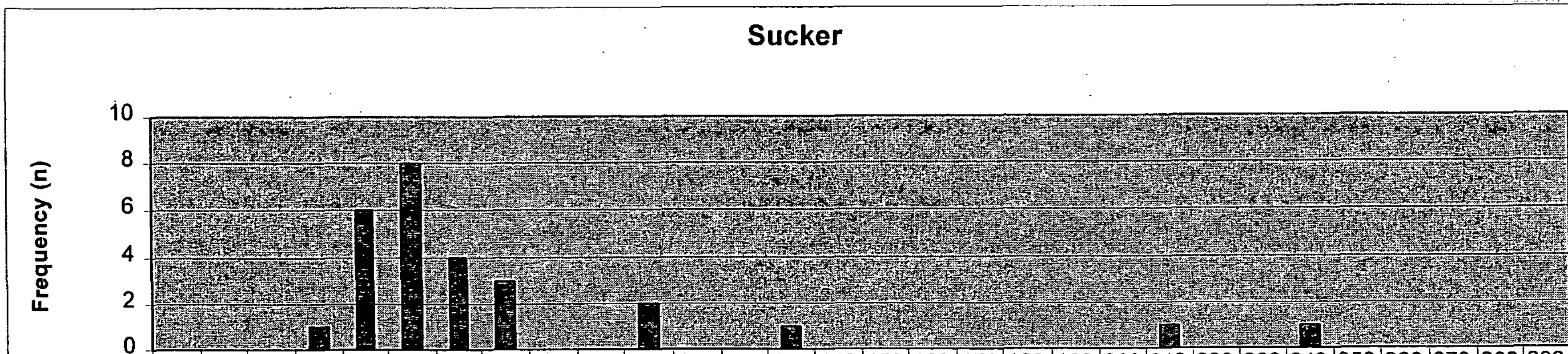
Rainbow Trout



	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	279	289	299
Rainbow Trout	0	0	0	0	4	6	8	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Length (mm)

Figure 9. Length frequency of rainbow trout collected at Site 4.



	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	279	289	299
Sucker	0	0	0	1	6	8	4	3	0	0	2	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0

Length (mm)

Figure 10. Length frequency of sucker collected at Site 4.

5.0 DISCUSSION

The distribution of fish in streams of the Willow Creek drainage is described in two reports, Bozeman et al., 1985, and Studley et al., 1995. Bozeman et al., 1985 conducted qualitative electrofishing surveys at 24 locations in Project streams and conduits during June 1984, and at 18 stations during low-flow conditions in August and September 1984, to determine seasonal distribution and relative abundance of fish (Figure 11).

None of the fish species inhabiting the Crane Valley Project Area are classified as rare, threatened, or endangered under the California Endangered Species Act (CESA) or the federal Endangered Species Act (ESA). Three hardhead (*Mylopharodon conocephalus*) were found in Willow Creek in 1984 (Bozeman et al., 1985). The hardhead is recognized by the California Resources Agency Department of Fish and Game as a Species of Special Concern (Moyle 1995) and by the US Forest Service Region 5 as a sensitive species (USFS 1998).

No hardhead were found during the quantitative electrofishing surveys conducted during 2000 at 3 locations on Willow Creek or at a location on Whisky Creek. It may be that the 3 specimens documented during the 1984 surveys represent what remained of a remnant population, the status of which is indeterminate, or it could be that the stream provides intermittent spawning and rearing habitat for fish migrating up from the Horseshoe Bend Reach of the San Joaquin River. The Horseshoe Bend Reach of the San Joaquin River sustains a healthy population of hardhead (Bianchi, 1997) and is currently designated as a Central Valley Drainage Hardhead/Squawfish Stream by the CDFG.

Hardhead are normally found in undisturbed low to mid-elevation streams in the Sierra Foothill areas and are usually found in the same habitat as Sacramento pikeminnow and Sacramento sucker. They are almost never found where pikeminnow are absent. Typically, hardhead do very poorly or are absent where introduced fishes, particularly centrachids (i.e. largemouth bass, smallmouth bass, or green sunfish) are present or in environments impacted by human activity (Moyle 1976).

Hardhead typically occur in warm, well-oxygenated streams with pools that are large and deep (greater than one meter in depth) and have sand-gravel-boulder bottoms. In laboratory studies, hardhead were shown to prefer water temperatures of 28.4°C (Knight 1985) and in the Pit River they were found inhabiting stream temperatures of 17 to 21°C, which were the warmest available. Hardhead prefer

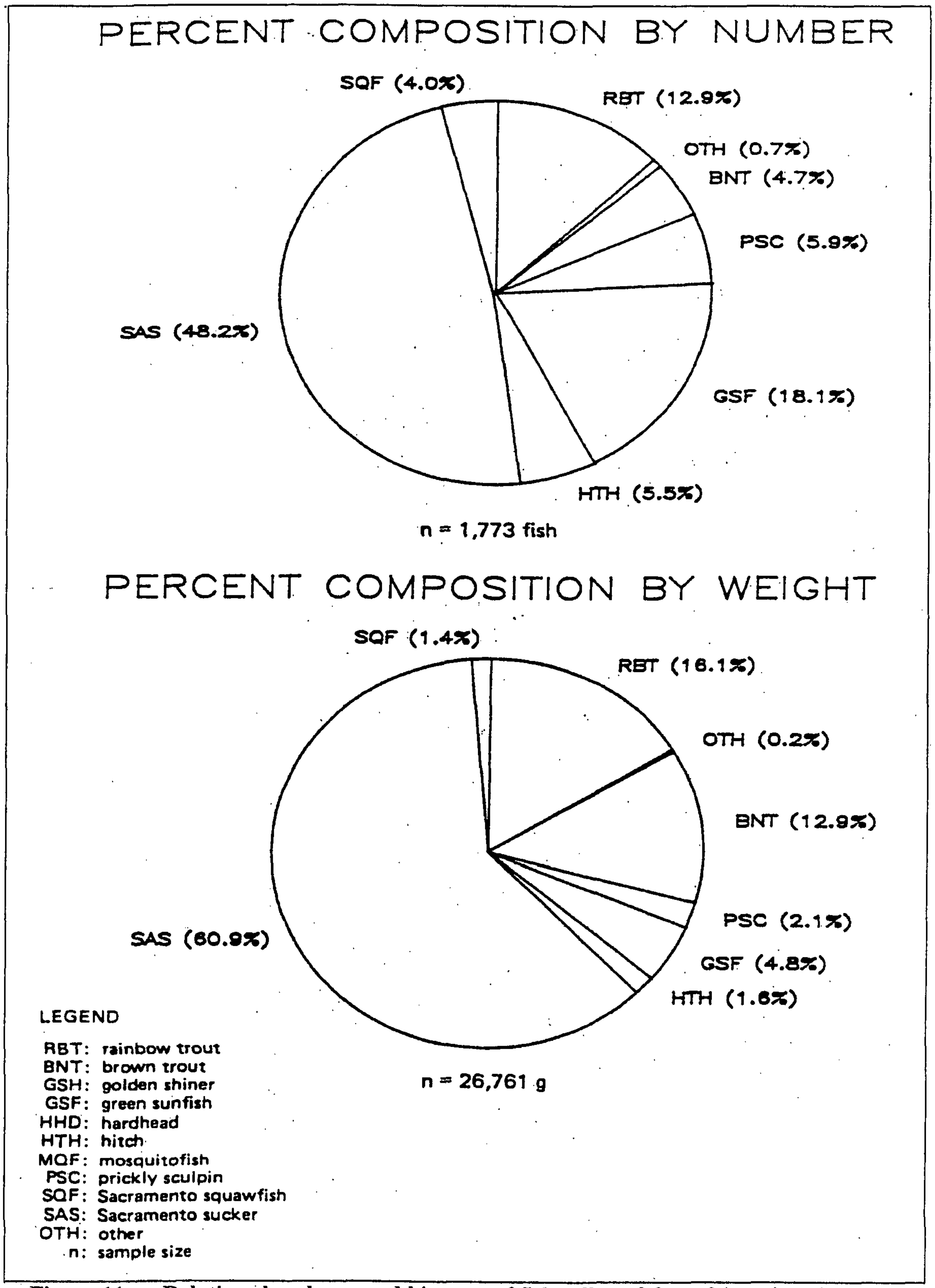


Figure 11. **Relative abundance and biomass of fish collected from 24 stations in the Willow Creek drainage in 1984 (Bozeman et al.)**

moderate stream velocities compared to preferences for species such as rainbow trout, (approximately 0.13 to 0.52 meters per second for adults and less than 0.06 m/s for juveniles), (BioSystems and University of California at Davis [UC Davis] 1985).

Hardhead feed mostly from the bottom, taking small invertebrates and aquatic plants in the quiet water of streams. They may also feed on plankton or surface insects on occasion. Younger, smaller hardhead in streams feed primarily on aquatic insect larvae, especially *baetid* mayfly or caddisfly larvae, and small snails. In lakes and reservoirs, young hardhead will feed mainly on planktonic cladocerans. As hardhead grow larger, their diet shifts to aquatic plants, especially filamentous algae. The fish probably do not get much nutrition from the aquatic plants, but rather get it from the small invertebrates that are taken incidentally with the plants (Moyle 1976).

Hardhead grow relatively quickly between one and three years of age. As the fish age, growth tends to slow. Hardhead may attain lengths of 460 mm FL by their sixth year, although this is uncommon in most locations. Hardhead are sexually mature at the end of their third or fourth years and spawn mainly in April and May (Reeves 1964, Grant 1992). However, Wang (1986) reports spawning from May through August in the upper San Joaquin River. Fish from larger rivers or reservoirs may migrate 30 to 75 km or more upstream in April and May, usually into smaller tributary streams (Reeves 1964). In small streams, hardhead may move only a short distance (either upstream or downstream) from their homepools for spawning (Moyle, In Press). In Pine Creek, Tehama Co., resident hardhead aggregate during the spawning season into nearby pools, while hardhead from the Sacramento River move up, presumably to spawn, into downstream reaches that dry up during the summer (Grant 1992). After hatching, the fry inhabit warm shallow water at the edges of streams or backwater (Moyle in press).

5.1 Hardhead Distribution and Abundance

Qualitative electrofishing surveys conducted by Woodward Clyde Consultants for PG&E in the spring of 1984 at 24 stations on Willow Creek, North Fork Willow Creek, and South Fork Willow Creek did not document any hardhead or Sacramento pikeminnow in any of the stream reaches above the Whisky Creek confluence with Willow Creek. Follow-up surveys conducted in the fall of 1984 at 18 of the original 24 stations also did not document evidence of hardhead or Sacramento pikeminnow above the confluence of Whisky Creek (Bozeman et al., 1985).

During October, 2000, a quantitative multiple pass depletion electrofishing survey of Whisky Creek (1 station), Willow Creek (1 station, approximately 300 yards above the confluence with Whisky Creek) and lower Willow Creek, at 2 stations was conducted. The lower Willow Creek stations were located 200 meters above USGS gauge 2465 (USGS gauge 2465 is located immediately above the Redinger Lake Road crossing), and 300 meters above the confluence of Willow Creek with the San Joaquin River (Figure 1). No hardhead were found and Sacramento pikeminnow were only taken at the 2 lower Willow Creek stations. A preliminary search of the literature indicates that, outside of the above mentioned studies, little or no historical data is available to document hardhead or Sacramento pikeminnow populations and distribution in Willow Creek.

5.1.1 Fish Community

The 1984 study documented only 3 hardhead and 71 Sacramento pikeminnow out of a total of 292 fish collected from two stations in lower Willow Creek. These two species, together, comprised 25.3% of the total fish caught. Hardhead comprised only 1.0% of that total. Sacramento sucker were more abundant at 184 individuals (63% of the total). The remaining 11.7% of the fish community was comprised of rainbow trout, brown trout, green sunfish, and prickly sculpin. Bozeman et al., 1985 does not specify, but these species (trout, sunfish, and sculpin) were likely caught at the upstream station (near our Site 3 above the Whisky Creek confluence), as surveys in 2000 did not document any of these species in the lower reach.

Of the 227 fish collected from the two lower Willow Creek stations in 2000, 209 were Sacramento pikeminnow (92.1% of the total) and the remaining 18 fish were Sacramento suckers (7.9% of the total. The apparent proportional increase in the number of Sacramento pikeminnow relative to the Sacramento sucker (209 pikeminnow / 18 suckers in 2000 versus 71 pikeminnow / 184 suckers reported in 1984) is likely attributable to the differing location of the stations between the 1984 surveys and the 2000 survey.

The 1984 surveys included a station that was located just below the confluence of Whisky Creek with Willow Creek. This station is notable in that, it is above a fairly high gradient reach of stream that may present passage barriers to Sacramento pikeminnow. It is also influenced by the coldwater input from Whisky Creek, a stream that maintains a healthy trout population. The two stations surveyed during the fall of 2000 were each located in the low gradient reach of Willow Creek near the confluence with the San Joaquin River, and visual surveys did not document any passage barriers for pikeminnow. Habitat in this lower reach is more typical of the classic hardhead-pikeminnow-sucker zone described by Moyle (1976) for low elevation California river reaches.

5.1.2 Length Frequency

The 3 hardhead documented in Willow creek in 1984 ranged in size from 84 to 130 mm. Sacramento pikeminnow ranged in size from 34 to 138 mm. The Sacramento pikeminnow collected in the fall of 2000 ranged in size from 33 to 138 mm. Of the 209 Sacramento pikeminnow collected in lower Willow Creek in 2000, only 11 fish were over 80 mm.

Visual surveys conducted in July of 2000 by PG&E, CDFG, and USFS biologists noted the presence of larger (possibly adult) cyprinids in some of the pools in this reach. Prior to the October 2000 electrofishing survey, it was thought that some of these minnows might be hardhead. The results of the electroshocking survey in October 2000 indicate that the fish seen in July were likely Sacramento pikeminnow. These data strongly suggest that Sacramento pikeminnow and hardhead (if present) are limited to the lower reach of Willow Creek. As mentioned above, this is likely a function of the high gradient, bolder and bedrock dominated reach that begins approximately ¼ mile above USGS gauge 2465. The cascades in this high gradient section present a number of probable passage barriers; habitat that is suitable for Sacramento pikeminnow and (presumably) hardhead is lacking. The lower reach of Willow Creek is typical of classic hardhead-pikeminnow-sucker habitat. It is characterized by large, deep, sandy-bottomed pools, fairly low gradient, and warmer stream temperatures.

Though the relative paucity (or absence) of hardhead in the lower section of Willow Creek is not understood, this reach appears to provide a very functional rearing habitat for cyprinids, and through inference, the presence of young-of-the-year Sacramento pikeminnow would indicate that some level of spawning activity occurs (at least for Sacramento pikeminnow). The apparent absence of adult Sacramento pikeminnow (and hardhead) may be more a function of the sampling techniques and the limitations imposed by electroshocking equipment for effectively sampling large deep pools. Many of the more typical pools in this reach are too large and deep to be effectively sampled with electroshockers and were therefore not sampled. Visual observations in July 2000 did indicate that large cyprinids were utilizing the larger, deeper pools. Visual observations of the larger pools in the same reach during the October 2000 electrofishing surveys noted a relative scarcity of adult cyprinids. Large numbers of young-of-the-year fish and smaller numbers of juveniles were observed, while only an occasional adult was seen.

5.2 Cyprinids in Upper San Joaquin River

Snorkel and electrofishing surveys conducted for Southern California Edison in 1985 and 1995 at several stations in the Horseshoe Bend Reach of the San Joaquin River indicate that large and healthy populations of hardhead, Sacramento pikeminnow, and Sacramento suckers utilize this reach. Redinger Reservoir and the San Joaquin River above Redinger Reservoir show a similar, native dominated species mix (SCE, 1997). Willow Creek joins the San Joaquin River at the upper end of the Horseshoe Bend Reach, and Redinger Reservoir is approximately 1 mile above this confluence.

5.2.1 Fish Community

Hardhead comprised the majority of the Horseshoe Bend Reach fishery in terms of abundance (60% in 1995) followed by Sacramento sucker (21%) and rainbow trout (10%). Sacramento pikeminnow and sculpin accounted for 5% and 3% of the fishery, respectively. Brown trout and threespine stickleback composed less than 1 percent of the fish community. The relative abundance of most species remained fairly constant between the 1985-86 and 1995 surveys, though Sacramento pikeminnow populations decreased from 13% of the total fish population in 1985 to 5% in the 1995 surveys (SCE, 1997).

5.2.2 Length Frequency

Hardhead, Sacramento pikeminnow, and Sacramento sucker populations were primarily composed of young-of-the-year fish, less than 75 mm in fork length (FL). The remainder of the hardhead population was fairly evenly distributed among size groups up to 400 mm FL, while a small number of Sacramento pikeminnow and Sacramento suckers were larger than 400 mm FL (Figure 12). Hardhead, squawfish, and sculpin had similar length-frequency distributions between the 1995 and 1985-86 surveys. In both surveys, hardhead and Sacramento pikeminnow populations were primarily composed of young-of-the-year fish (SCE, 1997).

5.2.3 Habitat Use

Fish distributions by habitat were evaluated for the species reported in the 1995 survey. All of the Sacramento pikeminnow, over 95 percent of the hardhead, and approximately 75 percent of the Sacramento sucker were observed in pool habitats. Habitat use by fish species was relatively similar between the 1985-86 and 1995 surveys for the hardhead and Sacramento Sucker. However, Sacramento pikeminnow were reported in all habitats in the 1985-86 surveys but were limited to pools in the 1995 surveys.

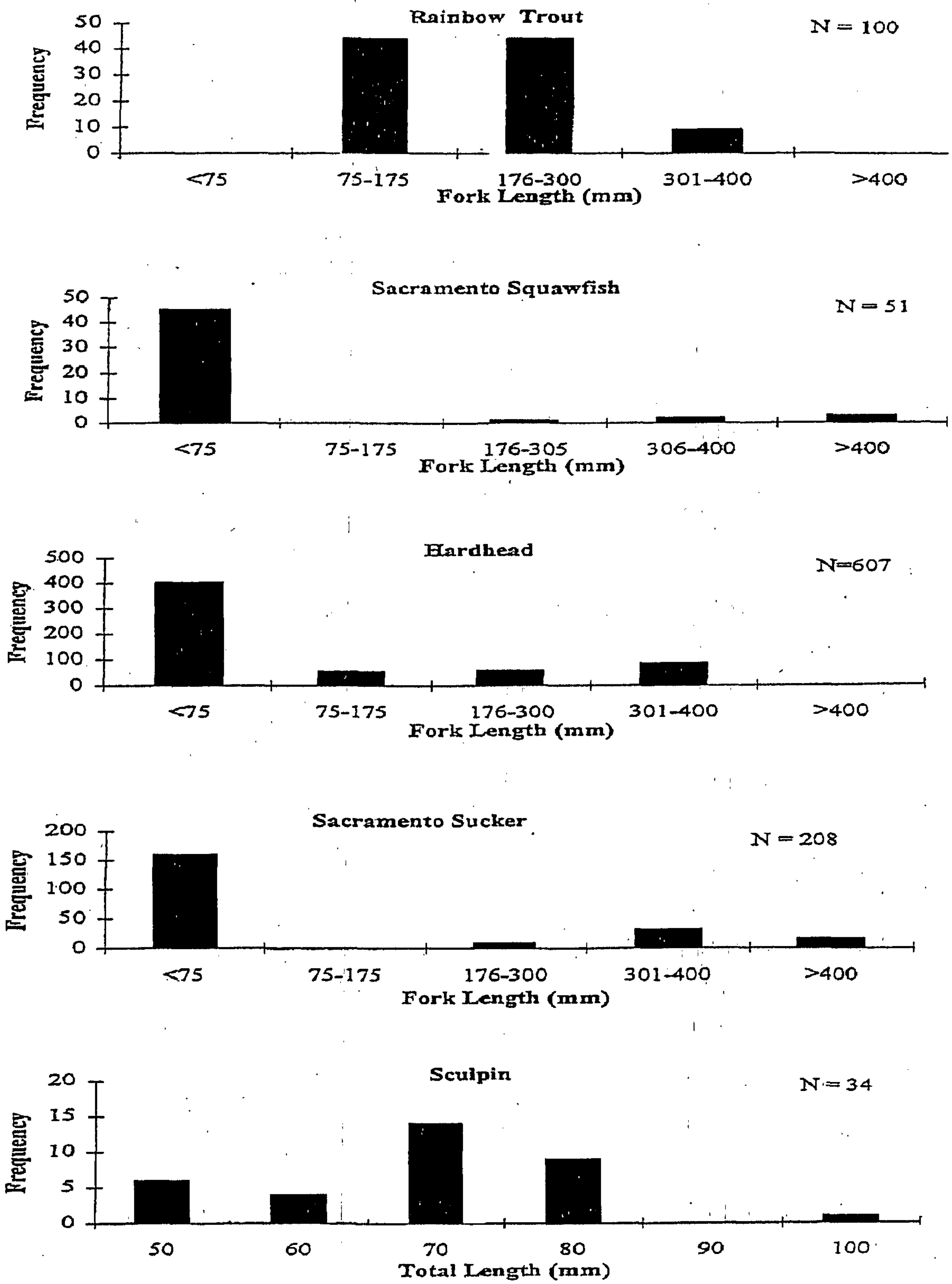


Figure 12. **Length frequency histgrams for native fish species sampled in the Horseshoe Bend Reach of the San Joaquin River in 1995 (SCE, 1997).**

6.0 CONCLUSIONS

Historically, hardhead were likely widespread and abundant in Central California. Hardhead are still widely distributed in foothill streams, but their populations are increasingly isolated from one another making them vulnerable to localized extinctions. As a consequence, they are much less abundant than they once were, especially in the southern half of their range. Reeves (1964) summarized historical records and noted they were found in most streams in the San Joaquin drainage, but in the early 1970s, Moyle found them in only 9% of sites sampled. Re-sampling many of the same sites about 15 years later Moyle found that a number of the populations had disappeared (Moyle, Personnel Communication).

In light of the relative abundance and seemingly healthy populations of hardhead in the Horseshoe Bend Reach of San Joaquin River, very little can be said about their paucity in the lower reach of Willow Creek. Interestingly, however, the converse seems to be true of the Sacramento pikeminnow population in these two streams. The Sacramento pikeminnow dominate the fish assemblage in lower Willow Creek (to the exclusion of any other fish species at one site surveyed during fall of 2000), yet they only comprise 5% of the observed population in the pool, run, pocketwater, riffle, and cascade habitats surveyed in the Horseshoe Bend Reach of San Joaquin River. The size distribution of Sacramento pikeminnow (almost entirely young-of-the-year and 1 year old fish) in Willow Creek illustrates its importance as a spawning/rearing habitat.

It is apparent that even absent the evidence for a resident population of hardhead in lower Willow Creek, the population is not only viable, but very healthy in the Horseshoe Bend Reach. It may be that the Horseshoe Bend population of hardhead uses lower Willow Creek for spawning and early season rearing, but absent any direct observation, it is impossible to verify any linkage between the river and lower Willow Creek. It is certainly reasonable to state that the present habitat conditions in lower Willow Creek are favorable for cyprinids. Further, the overwhelming presence of Sacramento pikeminnow (92.1% of the total fish assemblage during October, 2000 surveys) indicates that this stream section is particularly suited to cyprinids.

There is unusual geomorphology in this area creating a selective barrier that separates the fish habitat, resulting in opportunistic survival for predator and prey species. This separation of habitat is due to the loss of Willow Creek flow into a substantial sand lens, which occurs in the vicinity of the confluence with Whisky Creek. The sand lens reduces surface flow and water heats up due to solar radiation in Willow Creek above the confluence with Whisky Creek. The measured temperature of Willow Creek above the confluence was 29°C at mid-day. This compared with measurements of 19 degrees C in Whisky Creek and 21 degrees C in Willow Creek below Whisky Creek at about the same time.

The sand lens acts as a barrier that reduces surface flow and as a result water in pools heats up in Willow Creek above the confluence of Whisky Creek. Green Sunfish utilize this area for rearing, as most potential competitors are not adapted to these high temperatures. The sand lens provides a seasonal barrier that separates habitat areas for the fish. The trout generally stay below or in Whisky Creek where it is cooler, but a few take refuge in the deep pools above the Whisky Creek confluence, where they can find cool water from ground water accretion. Green sunfish were observed in the pools above the confluence of Whisky Creek where Willow Creek was flowing sufficiently to keep the pools refreshed. Although not observed in this study, young green sunfish trapped by zero flows, which occurs in dry years, would perish by late summer due to extremely high water temperatures (approaching ambient air temperature) and associated poor water quality. In wetter years, when there is sufficient flow for passage downstream, the green sunfish will be extremely successful and their predation could heavily impact hardhead and other fish populations.

If hardhead were present in Willow Creek, there would be sufficient habitat provided by the larger pool areas below the confluence of Whisky Creek to sustain a small population. Based on the abundance of hardhead in the San Joaquin River, hardhead would not make up a large percentage of the fish population. During winter flushing flows, hardhead, green sunfish, and other species of fish are washed out into the San Joaquin River.

The present understanding of hardhead biology, particularly habitat preferences and spawning times, locations, and migration patterns is very limited. Additional studies would be necessary to assess the lack of hardhead in Willow Creek. Available data indicate that there is an abundance of hardhead in the Horseshoe Bend Reach of the San Joaquin River. Recent surveys (SCE, 1997) indicate that the population is little different from what it was in 1985-86, but no data exist to indicate the historical utilization, abundance, or distribution of the species in lower Willow Creek. It may be that Willow Creek historically served only as a spawning and early season rearing location. Some form of environmental trigger (reduction in flows and/or increases in temperature) may cue young-of-the-year hardhead to move down into the larger pools in the Horseshoe Bend Reach of the San Joaquin River.

But not an abundance in Willow Creek

6.1 Cumulative Effects

Hardhead have a discontinuous distribution in the San Joaquin River drainage, present mainly in bedrock and boulder strewn sections of the main river and large numbers occur in Redinger Lake, a hydroelectric reservoir (SCE 1997). Hardhead were abundant enough in Central Valley reservoirs in the past to be regarded as a problem species, under the assumption they competed with trout and other game fishes for food. However, most reservoir populations proved to be temporary and were most likely the result of colonization by juvenile hardhead before introduced predators, such as small mouth bass, became abundant.

The principal mechanisms responsible for hardhead declines in the San Joaquin drainage appear to be habitat loss and predation by introduced centrachid fishes. Hardhead require large to medium-sized, cool to warm-water streams with deep pools for their long-term survival. Such streams are increasingly dammed and diverted, eliminating habitat, isolating upstream areas, and/or creating temperature and flow regimes unsuitable for hardhead. Consequently, populations are declining or disappearing gradually throughout its range. The few reservoirs in which hardhead are abundant today are those in which water-level fluctuations (such as for power-generating flows) prevent bass from reproducing in large numbers. However, either stabilization of water levels or increasing the amount of draw-down of these reservoirs (which expose small hardhead to predation) can result in increased populations of centrarchid basses and decreased hardhead populations.

While hardhead are still fairly common in the San Joaquin drainage, their general long-term decline is of concern and has resulted in their designation as a species of concern by both state and federal agencies. It would be prudent to stabilize hardhead populations in the San Joaquin River drainage while they still are at moderate levels. The best way to protect them would be to establish mid-elevation stream areas where stream flows are similar to natural regimes and high water quality is maintained. An abundant hardhead population is a good indicator of a relatively undisturbed biotic community of which they are a part. As hardhead populations are declining, stream populations should be monitored to make sure that the species is holding its own in the San Joaquin drainage area.

6.2 Management Recommendations

In developing an enhancement and mitigation program for hardhead and other fish species in Willow Creek, several factors were considered for determining appropriate management actions. These factors included (1) maintenance of Bass Lake surface elevations under existing operations to avoid adverse impacts on fisheries and recreation usage; (2) protection of Bass Lake fisheries from water quality and temperature impacts; (3) avoidance of secondary impacts on the downstream fishery from releasing water from Bass Lake at temperatures above 20°C (68°F); (4) release of flows sufficient to provide stream temperatures usable to both cold and warm water species, where feasible; (5) determination of release flows that would provide increased trout habitat availability; (6) provision for fish passage and pool continuity in Willow Creek; and (7) provision of release flows in a range that most efficiently increases habitat usability by fish per unit flow.

Opportunities for enhancement of fisheries resources vary significantly among the stream sections, depending on stream temperature, water availability, and the response of habitat availability to flow for the various life stages of fish species. Therefore, the management strategy for fish populations in Willow Creek was not based on targeting an arbitrary percentage of weighted usable area, as is typically done for trout species. The management strategy was developed by taking into account the above criteria and natural limiting factors. In Willow Creek, the enhancement opportunities are to provide for fish passage and pool continuity for the native catostomid, the Sacramento sucker, and the native cyprinids, hardhead and Sacramento pikeminnow.

A specific management strategy for the rainbow and brown trout occurring in the upper sections of the study area was not attempted. High summer water temperatures and poor substrate conditions make it impossible to create a year-round trout fishery in Willow Creek above Whisky Creek with existing operations. Temperatures in this segment exceed criteria for long-term trout exposure and growth (20°C, 68°F) and may occasionally exceed upper incipient lethal temperature (25°C, 77°F) (Bozeman et al. 1985 and Studley et al. 1995). Flow releases made under present operating conditions could not provide 100 percent usable temperatures for trout regardless of flow (up to 50 cfs) (PG&E 2001). Below Whisky Creek from January to June, existing flows provide near maximum trout habitat. In July and August, flows less than 20 to 25 cfs provide no trout habitat. In September, under existing operations, usable salmonid temperatures cannot be obtained at any flow.

In lieu of any data to indicate otherwise, lower Willow Creek was considered an important component of the available hardhead habitat in the Horseshoe Bend Reach of the San Joaquin River. The proposed increase in water releases to North Fork Willow Creek (from 0.5 cfs to 2 cfs) will not appreciably alter water temperatures in lower Willow Creek, but should provide more late-season passage opportunities for hardhead (PG&E 2001).

Knight (1985) concluded that optimal temperatures for native fishes in lower elevation streams of the Sacramento-San Joaquin River system should range between 25°C and 30°C. He found that the acute final temperature preferenda (the temperature that fish will select given a range of temperatures) for Sacramento pikeminnow and hardhead were 26.0°C and 28.4°C, respectively. Although a final temperature preferendum was not determined for Sacramento sucker, limited data suggested that it was around 26.0°C (Knight, 1985). Insufficient data were available to set a maximum temperature criteria for all species; however, an instantaneous maximum temperature of 37.0°C or more could result in mortality of Sacramento pikeminnow and is assumed likely to be lethal for the other native species as well. It is apparent that the late season water temperature regimes in lower Willow Creek are currently within or slightly less than the optimal temperature range of between 25°C and 30°C (Knight, 1985). A potential management strategy could be to maintain this separation of species by regulating stream flows. Perhaps by regulating stream flow to minimize the connection between Willow Creek above and below the sand lens.

Based on the above results and a literature review of habitat requirements for hardhead and green sunfish, it seems most appropriate to minimize the risk of moving large numbers of green sunfish into lower Willow Creek where they would likely prey on the juvenile hardhead during the low flow season. An initial minimum flow release of 0.5 cfs in Willow Creek is recommended to prevent stagnation, but not high enough to allow movement of the green sunfish and other introduced species into lower Willow Creek during summer low flow periods. This minimum flow release would take advantage of the predatory nature of green sunfish to reduce their own populations during the low flow seasons. When spill flows do occur in the winter and spring and the flow in Willow Creek is high, there is a corresponding high flow in the San Joaquin River, thus keeping the green sunfish moving into Kerckhoff Lake and below into Millerton Lake where the green sunfish would experience numerous predators.

6.3 Continuing Investigations

There are several potential investigations on the lower Willow Creek hardhead population that would illuminate the limiting factors of this sensitive fish population. Consultations with Dr. Peter Moyle at UC Davis have revealed several potential studies that could further our knowledge of hardhead biology and the mechanisms that may control use of Willow Creek by this species[2].

[2] Note, outside of satisfying scientific curiosity, further study of lower Willow Creek may not provide much that is useful from a resource management perspective. Proposed mitigation for the new license will increase flows in Willow Creek to 0.5 cfs initially and instream flows may be increased to a maximum of 2 cfs to meet stated management objectives. Native cyprinids do not appear to have significant limitations, from a habitat perspective, under current or proposed conditions.

- Larval Trapping During Spring Spawning Period
- Electrofishing During Spring Spawning Period
- Snorkel Surveys During Spring Spawning Period
- Gillnetting During Spring Spawning Period

The above studies could verify if hardhead utilize lower Willow Creek for spawning/early season rearing. Gillnetting and/or Snorkeling could be conducted during the spring and early summer months to look for the presence of adults in this reach. It would be appropriate to investigate the benefit of varying minimum flow releases in lower Willow Creek through the range of 0.5 to 2 cfs to determine the best flow to protect sensitive aquatic species, such as hardhead and amphibian species, by providing pool continuity, fish passage between pools, and acceptable water quality, while minimizing the potential for centrachid predators from moving downstream during critical periods.

Competition between introduced fish species and native fish should be evaluated. A competitive interaction study could address the following questions:

1. What is the competitive interaction between green sunfish and hardhead? Peter Moyle suggests that in most situations green sunfish are rarely abundant in hardhead habitat. Although there is evidence that significant competitive interactions between smallmouth bass and hardhead occur, (Brown, L. R. and P. B. Moyle. 1993), there is little in the literature concerning green sunfish and hardhead competition.

2. If any competition between green sunfish and hardhead occurs, it will likely be through predation on hardhead larvae. These interactions are difficult to study because most of the predation is likely to occur in a very narrow window of time. Predatory behavior may also have a seasonal temperature component; such as higher predation rates at higher water temperatures. Peter Moyle suspects the opposite is also true; when spring temperatures are optimal for hardhead and pikeminnow spawning, they can produce large numbers of young of the year that would be large enough to prey on sunfish larvae when temperatures are finally warm enough for green sunfish spawning (Peter Moyle, personal communication). An understanding of native versus introduced species predation rates and how they vary with seasonal temperatures would provide basic data for an effective management strategy.

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