3.3 Steelhead Populations

3.3.1 Introduction

Land management, water development, and flow management have all contributed to the decline of salmon and steelhead in the Central Valley. However, the mechanisms by which these impacts have occurred have not been the same for all species and races. Whereas chinook spawning habitat is largely still available in the mainstem San Joaquin River, dams have blocked access to historical steelhead spawning and rearing habitat, forcing steelhead to spawn and rear in lower-elevation reaches where water temperatures are often lethal (Yoshiyama et al. 1996, McEwan 2001). Loss of spawning and rearing habitat is believed to have had the single-greatest impact on steelhead populations in the Central Valley (McEwan 2001).

The historical distribution of steelhead in the San Joaquin River is not well known. However, in other drainage basins they are usually more widely distributed than chinook salmon, and likely spawned and reared in tributaries above Friant Dam (Yoshiyama et al. 1996, Voight and Gale 1998, as cited in McEwan 2001). One reason for the wider distribution than chinook is that steelhead typically spawn in tributaries where chinook salmon tend to spawn in mainstem channels. Based on the historical distribution of chinook salmon in the San Joaquin River, steelhead likely also occurred at least as far upstream as Mammoth Pool (RM 322) in the San Joaquin River, and probably occurred in many of the small tributaries as well (Yoshiyama et al. 1996). Very little habitat suitable for steelhead spawning and rearing is currently accessible in the San Joaquin River basin. The mainstem San Joaquin River, similar to other large streams, is characterized by substrates that are probably too coarse for steelhead spawning; steelhead would also have to compete with chinook salmon in these reaches. Therefore an appropriate restoration strategy to reintroduce and enhance steelhead populations is fundamentally different than the strategies to enhance chinook salmon.

The vision for restoring steelhead focuses on enhancing steelhead habitat in tributaries downstream of Friant Dam. The construction of Friant Dam blocked access to many of the upper San Joaquin River tributaries with potential steelhead habitat. Because access to upper reaches is blocked, and steelhead habitat is extremely limited in the remaining San Joaquin basin, augmenting flows in suitable tributaries may be the best method for reintroducing a steelhead population. Stillwater Sciences surveyed the tributaries downstream of Friant Dam for their potential as steelhead reintroduction sites. These tributaries are typically dry during the summer and fall months, and so would not have supported year-round rearing of steelhead under historical conditions. The initial selection for enhancement sites focused on tributaries that have a potential supply of cool water. Cottonwood Creek and Dry Creek were selected for more detailed analysis because they have potential for obtaining flows from nearby irrigation canals. They are intermittent so there is no potential for stocked steelhead to affect native resident fish, and fry or juveniles that outmigrate would have suitable rearing habitat in the mainstem (Appendix B, Figures B-8 and B-9). Reconnaissance field surveys were conducted in the two tributaries to assess the potential for steelhead enhancement. Following the initial field assessment, Cottonwood Creek was surveyed to obtain a more detailed assessment of potential production and opportunities for enhancement. Stillwater Sciences and a steelhead expert (Dr. Bill Trush, McBain & Trush, Arcata, California) surveyed Cottonwood Creek in September 2002 to evaluate its potential as a steelhead reintroduction site. The survey was restricted to the lower 6,000 ft (1830 m) of stream where flows could be augmented using water from Madera Canal. The goals of the habitat survey were to (1) estimate the amount of potential steelhead spawning and rearing habitat in the reach in order to calculate the number of smolts that could be produced, and (2) estimate the instream flows that might be required to achieve this level of smolt production based on physical habitat requirements.

If flow were provided from the Madera Canal to Cottonwood Creek, approximately 6,000 ft (1830 m) of channel could be augmented with flow year-round. It appears from the analysis that with an augmented flow of 20 cfs, a spawning population could be sustained in Cottonwood Creek, with an annual production of about 1,000 smolts; however, if a restoration strategy involving Cottonwood Creek is pursued, more analysis will be required. Habitat conditions in Little Dry Creek also appear promising for steelhead restoration, although constraints in Little Dry Creek present far more of a challenge than in Cottonwood Creek.

It is very likely that flow management of the mainstem San Joaquin River that is designed to restore chinook populations will be adequate to support the upstream and downstream migration of steelhead, and may improve mainstem rearing habitat for steelhead as well. However, because steelhead restoration will require further efforts in tributaries, and because juvenile steelhead are known predators on juvenile chinook, it is not prudent to initiate their restoration at this time. Rather, after the reintroduction efforts for chinook, it is anticipated that habitat conditions will be suitable for steelhead in the mainstem. There appears to be less known about steelhead in the Central Valley than salmon, and the delay in efforts to restore steelhead will provide time for advancements in steelhead biology to inform a potential restoration strategy. A general vision of the restoration strategy for steelhead is provided below. During the adaptive management experiments that will be needed to reestablish chinook, a more detailed steelhead strategy can be developed.

Restoring a self-sustaining population of steelhead to the San Joaquin River should be pursued after self-sustaining chinook salmon populations have become well-established and can tolerate the additional predation pressure in upstream reaches that steelhead may represent. Steelhead rear for up to two years in fresh water before outmigrating to the ocean, during which time they attain sizes capable of preying on fry and smaller juvenile salmon. Because juvenile steelhead would be present year-round in the same cold-water reaches as fry and juvenile chinook salmon, they may pose a larger threat than non-native species in warmer reaches that would only be expected to prey on juvenile salmon during outmigration.

3.3.2 Potential sources of parent stock

There are potentially several parent stocks for restoration of steelhead to the San Joaquin River. CDFG recommended that a parent stock be selected based on an analysis of steelhead genetics being conducted by Jennifer Nielson that is expected to be completed in summer 2003 (Katie Perry, CDFG, pers. comm.). This analysis is addressing the genetic relationships between and within populations of Central Valley steelhead and rainbow trout, and specifically examines San Joaquin basin steelhead from the Kings River, Calaveras River, upper and lower Tuolumne River, and upper and lower Stanislaus River. Steelhead also occur in the Mokelumne River and are propagated by Nimbus Hatchery, but genetic analysis confirms that these fish originated in the Eel River and are therefore not suitable for use as a parent stock (Katie Perry, CDFG, pers. comm.). Once a parent stock is selected, life history timing and habitat requirements can be defined and lend focus to other components of the restoration strategy.

3.3.3 Steelhead life histories and habitat considerations

3.3.3.1 Upstream migration

In the Central Valley, adult winter steelhead migrate upstream during most months of the year, beginning in July, peaking in September, and continuing through February or March (Hallock et al. 1961, Bailey 1954, both as cited in McEwan and Jackson 1996). Because their migration timing overlaps with fall chinook, flow enhancement designed for fall chinook migration in the mainstem San Joaquin will likely benefit steelhead as well.

Steelhead are among the strongest swimmers of freshwater fishes, and are known to be faster and able to leap much larger obstacles than chinook (Bjornn and Reiser 1991). Therefore, flows designed for fall chinook migration can be expected to be suitable in velocity for steelhead, and passage facilities at migration barriers designed to accommodate chinook will also be suitable for steelhead.

For adult steelhead migration, temperatures ranging from 46 to 52^{o}F (8 to 11^{o}C) are considered to be preferred (McEwan and Jackson 1996), while temperatures exceeding 70^{o}F (21^{o}C) are stressful (Lantz 1971, as cited in Beschta et al. 1987). Chinook have far more restrictive migration habitat requirements in terms of flow depth, water velocity, and temperature, and it is very likely that migration conditions favoring their restoration will benefit adult steelhead migration in the San Joaquin River mainstem.

A steelhead restoration strategy for Cottonwood Creek would likely require providing increased flows in the spring and fall for upstream and downstream migration cues, in addition to minimum base-flows. At an estimated flow of 20 cfs, water depth or velocity is unlikely to inhibit adult steelhead migration. Because water velocity varies across a channel, it is very likely that suitable water velocities for spawning would be available in Cottonwood Creek at 20 cfs, especially in pool tailouts, where modeled water velocities at 20 cfs ranged from 1.0 to 8.0 ft/s (0.31 to 2.44 m/s).

3.3.3.2 Adult holding

During their upstream migration, adult steelhead require pools for resting and holding (Puckett 1975, Roelofs 1983, both as cited in Moyle et al. 1989). Such pools should be available in the San Joaquin River during fall and winter as a result of implementing the chinook restoration strategy.

3.3.3.3 Spawning

Adult steelhead prefer to spawn in streams with water depths from about 7.0 to 53.4 in (18 to 137 cm) and velocities from 1.97 to 3.77 ft/s (0.60 to 1.15 m/s) (Moyle et al. 1989, Barnhart 1991). Pool tailouts or heads of riffles with well-oxygenated gravels are often selected as redd locations (Shapovalov and Taft 1954). Gravels ranging in size from 0.25 to 5.1 in (0.64 to 12.9 cm) in diameter are suitable for redd construction (Barnhart 1991). These conditions most often occur in small, high gradient streams, which are the preferred spawning locations for steelhead. Steelhead may even spawn in intermittent streams, but juveniles soon move to perennial streams after hatching (Moyle et al. 1989). Bell (1986) indicates that preferred temperatures for steelhead spawning range from 39.0º to 48.9ºF (3.9º to 9.4ºC). As described above, most of the tributaries that historically provided spawning habitat are currently blocked by the Friant Dam.

Most spawning habitat identified in the mainstem San Joaquin River is too coarse for steelhead, although it is likely that substantial spawning could occur in isolated patches in upper Reach 1. Cottonwood Creek was examined as a potential spawning tributary as it probably approximates historical steelhead habitat. Nine patches of suitable steelhead spawning gravel were found in the 3,400-ft (1037-m) surveyed reach of Cottonwood Creek, totaling 200 ft^2 (18 m^2). Based on the professional judgment of the surveyors, all patches identified could be used by at least one adult pair. There appeared to be opportunities for gravel augmentation, which could double or triple the amount of suitable spawning habitat. A HEC-RAS model was used to simulate depths and velocities that would result from various discharges. Model inputs included thalweg elevations measured over a 260-ft (79.3-m) surveyed reach, and three cross sections. The results of the simulations indicated that with 20 cfs of augmented flow, depths and velocities would be suitable for spawning in the observed patches in Cottonwood Creek. Temperatures during the winter, when steelhead are spawning and eggs are incubating, appear to typically be cool, and are not likely to be a concern in Cottonwood Creek. This reach is likely to produce less than 1,000 smolts based on our estimates of available spawning habitat and our assumptions about the productive potential for steelhead. Spawning habitat appears to be limiting steelhead production and if spawning habitat is augmented, the number of smolts could be increased dramatically.

3.3.3.4 Freshwater rearing

Juvenile steelhead (parr) rear in fresh water before outmigrating to the ocean as smolts. The duration of time parr spend in fresh water appears to be related to growth rate, with larger, faster-growing members of a cohort smolting earlier (Peven et al. 1994). In warmer areas, where feeding and growth are possible throughout the winter, steelhead may require a shorter period in fresh water before smolting, while steelhead in colder, more northern, and inland streams may require three or four years before smolting (Roelofs 1985).

Older juvenile steelhead (age 1+ and older) occupy a wide range of hydraulic conditions. They prefer deeper water during the summer and have been observed to use deep pools near the thalweg with ample cover, as well as higher-velocity rapid and cascade habitats (Bisson et al. 1982, Bisson et al. 1988). Age 1+ fish typically feed in pools, especially scour and plunge pools, resting and finding escape cover in the interstices of boulders and boulder-log clusters (Fontaine 1988, Bisson et al. 1988). The minimum size at which juvenile steelhead become piscivorous is typically assumed to be about 11 in (25 cm), based on studies on brown trout (Bachman 1991). It is likely that some age 2+ or older steelhead could grow to a piscivorous size prior to outmigrating, and may pose a predation risk for emergent chinook fry. Enhancing habitat in tributaries to the San Joaquin River will encourage habitat segregation between steelhead and chinook, and decrease potential predation. In addition, steelhead restoration efforts will be delayed until chinook populations are established.

It is likely that suitable rearing habitat will exist for steelhead in the mainstem San Joaquin River, particularly in upper Reach 1. A stocked rainbow trout fishery in upper Reach 1 is currently successful, indicating that water temperatures and habitat complexity in this part of the mainstem are adequate to support rearing steelhead. However, younger age classes would benefit from shallow, complex habitat more typically found in tributaries. Surveys were conducted in Cottonwood Creek to enumerate the amount of suitable rearing habitat for juvenile steelhead. Approximately 55,415 ft^2 (5,148m^2) of optimal juvenile steelhead rearing habitat was delineated in the 3,400-ft (1040-m) reach surveyed. Rearing habitat is unlikely to limit steelhead production based on the estimated numbers of steelhead that can be produced from the limited available spawning habitat.

An augmented flow of 20 cfs from the Madera Canal would provide suitable steelhead rearing habitat based on examination of HAC-RAS modeling for Cottonwood Creek. At a discharge of 20 cfs, pool depths would range from 2 to 4 ft (0.6 to 1.2 m), and riffle depths would range from

0.49 to 2 ft (0.15 to 0.3 m) Average water velocities would range from 0.3 to 1.5 ft/s (0.09 to 0.46 m/s) in the pools, and up to 8 ft/s (2.4 m/s) in riffles. The stage height at 20 cfs would partially inundate a lower bench, above the existing silt line, and below bankfull depth. Based on field observations, a majority of the habitat in the channel would be suitable for juvenile steelhead rearing at this flow, and would be well within their preferred depth and velocity requirements (Appendix B, Figure B-10).

Water temperature has a strong influence on almost every life history stage of steelhead (Berman 1998), though the specific thermal requirements of steelhead are not well understood (McEwan 2001). In summer, Central Valley steelhead are well adapted to higher temperature ranges, with preferred rearing temperatures ranging from 63 to 68°F (17 to 20°C) and a maximum temperature tolerated (lethal critical thermal maximum) of 80°F (27°C) (Myrick 1998). However, other environmental conditions also indirectly influence habitat suitability at higher temperatures. For example, if food availability is high, fish have a much higher tolerance for high temperature.

Water temperatures in an enhanced Cottonwood Creek would principally be determined by the temperatures in the Madera Canal. Millerton Lake is thermally stratified, thus lake elevation influences the temperatures in the Madera Canal (446.0 FMSL). In all but drought conditions, lake levels are high enough that this discharge height lies below the seasonally warm epilimnion of Millerton Lake. Unfortunately, no temperature data are available for the Madera Canal, and the only representative available data are for the Friant Kern Canal (464.0 FMSL), which were collected by the USGS during monthly water quality tests between 1975 and 1981. The utility of the Friant Kern data is limited here, since the seasonal thermocline structure of Millerton Lake was not measured. Temperatures during the summer (July to October) do exceed preferred temperatures (<68ºF [<20ºC]). However, the maximum tolerated temperature (lethal critical thermal maximum) of 80°F (27°C) is rarely exceeded. Improving these estimates would require extensive modeling and/or the accumulation of thermal profile data at the dam face. Although the Friant Kern temperature data may overstate the temperature risk to steelhead, it does not appear that summer rearing temperatures are high enough to preclude a steelhead population. However, there is some risk of extended periods of high summer water temperatures >68º (>20ºC), and this could potentially limit production. It is likely that sublethal temperature effects, including and susceptibly to disease, may be an issue. A multiple-year record of continuous temperature data from the Madera Canal should be collected and analyzed before any enhancement is implemented in Cottonwood Creek. It is likely that the amount of flow released into Cottonwood Creek will also influence water temperature. Modeling to determine the relationship between flow and water temperature may be a primary factor affecting selection of flows for augmentation.

3.3.3.5 Smoltification and outmigration

At the end of the freshwater rearing period, steelhead migrate downstream to the ocean as smolts, typically at a length of 5.9 to 7.8 in (15 to 20 cm) (Meehan and Bjornn 1991). A length of 5.5 in (14 cm) is typically cited as the minimum size for smolting (Wagner et al. 1963, Peven et al. 1994). In the Sacramento River, steelhead generally emigrate as 2-year-olds during spring and early summer months, although outmigration can occur during any month of the year (McEwan 2001), and appears to be more closely associated with size than age.

Estuarine rearing may be more important to steelhead populations in California than farther north due to greater variability in ocean conditions and paucity of high quality near-shore habitats in this portion of their range (NMFS 1996a). However, estuaries may be less important to populations spawning in the Central Valley than in smaller coastal tributaries, due to the more limited availability of rearing habitat in the headwaters of smaller stream systems (McEwan and

Jackson 1996). Most marine mortality of steelhead occurs soon after they enter the ocean, primarily due to predation (Pearcy 1992, as cited in McEwan and Jackson 1996). Because predation risk and fish size are likely to be inversely related (Pearcy 1992, as cited in McEwan and Jackson 1996), the growth that takes place in estuaries may be very important for increasing the odds of marine survival (Pearcy 1992, as cited in McEwan and Jackson 1996; Simenstad et al. 1982, as cited in NMFS 1996a; Shapovalov and Taft 1954). The importance of estuaries is a critical uncertainty in the San Joaquin system, and further research may be required to develop an appropriate restoration strategy for steelhead.

The preferred outmigration temperature is generally <57°F (<13°C) (McEwan and Jackson 1996). Myrick (1998) provides the only assessment of temperature tolerances specifically for Central Valley steelhead. These experiments used steelhead that were reared at the Mokelumne River State Fish Hatchery from eggs that were collected at the Nimbus Fish Hatchery (American River). These experiments indicate that Central Valley steelhead prefer higher temperature ranges than those reported in the literature for other stocks, with preferred rearing temperatures ranging from 63 to 68°F (17 to 20°C) and a maximum temperature tolerated (lethal critical thermal maximum) of 80°F (27°C). Water temperatures in Reach 5 and farther downstream are warmer than 68ºF (20ºC) for much of the year, which may cause steelhead to delay outmigration until temperatures are lower during pulse flows provided for chinook migration. The chinook restoration strategy includes a pulse flow in February and March of approximately 1500 cfs. Modeled water temperatures at this flow indicate that temperatures will be less than 60ºF (15.6ºC) from Reach 1 downstream to the confluence with the Merced River, where temperatures drop due to the cool receiving waters from the Merced. Although steelhead can outmigrate in any month of the year, it is likely that migration will peak during this period of higher flows and lower water temperatures.

It is unlikely that the number of outmigrating steelhead will be large enough to saturate predators, as may be achieved with chinook. However, steelhead typically outmigrate at about 6 in (15 cm), which is large enough to avoid predation.

.