3.4 Resident Fish Populations

3.4.1 Introduction

Under current conditions, resident fish communities of the mainstem San Joaquin River consist of both native and non-native species. Most of the resident native fish species that historically existed in the mainstem San Joaquin River are still present, although the abundance and distribution of many species has substantially declined, especially on the valley floor. Even the most ambitious restoration program will not completely eradicate populations of non-native resident fish species. One of the primary reasons is that their life histories and habitat requirements overlap with those of many native resident fish, most notably those belonging to the deep-bodied fish assemblage. Efforts to reduce suitable spawning, rearing, and adult habitat for non-native species would thus reduce habitat for certain native species as well. Similarities in life histories and habitat use are one reason why many of the native species have declined. A prime example is Sacramento perch, which have life histories and habitat requirements that overlap with introduced centrarchid species. The Sacramento perch has been extirpated from its native range in the San Joaquin River, but the species persists in other areas and reintroduction therefore remains a possibility.

This section describes an overall vision for restoration of resident fish communities in the mainstem San Joaquin River and explores the habitat requirements of a set of species chosen to represent the needs of the larger native fish community as a whole. These habitat requirements were then evaluated in relation to habitat changes likely to result from measures to restore chinook salmon, because the highest priority for restoration in the project area has been assigned to restoring chinook salmon populations. Where native resident fish needs did not appear adequately addressed by measures designed for restoring chinook salmon and their habitat, we evaluated potential ways of addressing these needs with additional restoration components. These restoration components (i.e., the actions necessary to achieve the vision described in this section) for resident native fish are discussed in Section 3.4.6.

Although this section focuses on resident fish communities, it includes discussion of Pacific lamprey and river lamprey, which are anadromous species, because they have habitat requirements that may not be met by strategies for anadromous salmonids.

3.4.2 Overall vision and objectives for resident fish communities

The overall vision for the resident fish community in the project area is to maintain, enhance, or restore naturally reproducing populations of all native resident fish and lamprey species, including the currently extirpated Sacramento perch, even if some species may occur primarily in isolated habitats. Ideally, all native species that historically occurred in the project area would be restored to healthy populations that inhabit their original distribution; however, this objective may be unrealistic due to current demands for water and surrounding land uses. Non-native fish species will continue to co-exist with native resident and anadromous fish in most reaches, but restoration measures will reduce competition with and predation on native species through reducing habitat quality and quantity for non-natives.

To attain the vision and objectives, strategies for resident fish were developed with the following priorities:

- Maintain all extant populations of native fish species, and provide conditions necessary to

maintain viable, well-distributed populations of these species wherever possible.
- Increase the abundance and distribution of species that have declined by restoring or enhancing the types of aquatic habitats, habitat characteristics, or hydrologic characteristics that were available under historical conditions in the project area, even if not in the same quantity or distribution as they historically occurred.

Specific measures included in one or more strategies to achieve these objectives include:
- Inundating floodplain habitats in spring for Sacramento splittail and other native floodplain spawners.
- Enhancing spring flows to improve spawning habitat for native riffle-spawning species.
- Providing opportunities for reintroducing Sacramento perch into the San Joaquin basin by designing some perennial wetlands for this purpose.
- Establishing a native fish community in Mendota Pool for public education purposes and to provide a source of native fish stock for seeding other habitats as they are restored or enhanced.
- Enhancing habitat connectivity for native fish where currently impaired.

3.4.3 Assumptions governing development of strategies for resident fish communities

Analysis of potential effects of restoration strategies on resident fish populations will be largely qualitative due to lack of quantitative information on the abundance and distribution of many of these species and general gaps in the understanding of these species' biology and habitat requirements. Many of the restoration strategy hydrographs are designed to provide suitable temperatures for chinook salmon to successfully complete their life cycle. Because these species evolved in the same river systems as those used by chinook salmon, many of their flow-related habitat needs may be met by the same hydrographs, with some minor adjustments. Most of the information used to determine appropriate measures for native resident fish was drawn from what is known about their temperature and habitat preferences.

Some native resident species will likely benefit from restoration measures designed for chinook salmon, while others may require additional measures to address their habitat and instream flow needs. The needs of some native fish species, or at least certain of their life stages, will likely be met through implementing restoration measures for chinook salmon and riparian vegetation, especially riffle-spawning species, riffle sculpins, and Sacramento splittail. Fish in the deep-bodied fish assemblage that are adapted to low-elevation, valley-floor habitats, such as hitch, Sacramento blackfish, and Sacramento perch, are less likely to benefit from measures to improve habitat for chinook salmon. These species, however, may benefit from measures designed to reduce predation on outmigrating smolts by reducing the abundance of non-native fish species. Some species may be negatively affected by strategies focusing on chinook salmon needs. For example, the larval stages of Pacific lamprey live burrowed in mud and fine sediment in low-velocity habitats such as channel margins and backwaters from four to six years before metamorphosing to the young adult stage. Seasonal flow fluctuations focused solely on fulfilling the needs of anadromous salmonids may dewater or drown shallow backwater habitats used by larval lamprey, mobilize gravels in nests, or dewater nests.

Non-native species will continue to persist in the basin, but restoration measures may be able to reduce negative interactions between certain native and non-native fish populations by reducing the distribution and abundance of non-native species through managing flows to more closely resemble natural hydrologic regimes.

Restoration measures to enhance native resident fish populations, native anadromous fish populations, and riparian vegetation include components that aim to reduce the abundance and distribution of non-native fish species. These measures do not include direct control measures and are not expected to result in short- or long-term extirpation of any non-native species in the project area. The continuing presence of non-native species and the likelihood that there will be future unwanted introductions do not necessarily spell doom for native fish species; however, human land use and competing demands for water limit the potential for restoring natural hydrologic regimes and habitats in the basin.

Native fish species in the San Joaquin basin are adapted to widely fluctuating but relatively predictable seasonal changes in stream flows, multi-year periods of extreme drought, and occasional large floods. Many species are relatively long-lived and can persist through several years of poor recruitment if spawning and rearing conditions are not suitable. Stable flows appear to favor non-native species, many of which may be able to spawn repeatedly throughout the spring and summer if temperatures remain suitable (Baltz and Moyle 1993; Moyle and Light 1996a, 1996b; Brown and Ford 2002). Brown and Ford (2002) found that the model that best predicted the proportion of non-native species in the Tuolumne River included both river kilometer and mean daily April/May discharge in the previous year, supporting the hypothesis that differential spawning success of native and non-native species during the previous spring was important in determining fish community structure in that stream. They noted that elevated spring flows occurred in unimpaired hydrographs even in years of low outflow, and suggested that this component of the seasonal flow regime may be partially responsible for the continuing dominance of native species in some of the less altered streams in California such as Deer Creek. High flows in the spring that maintain cooler temperatures later into the spring may facilitate early spawning by native fish that can then grow large enough by late spring to prey on non-native fish larvae and fry. If temperatures warm up early in the spring spawning season, both native and non-native fish may spawn at approximately the same time and predation on native fish by non-natives is likely to be higher (P. B. Moyle, pers. comm., 2002). Inundating floodplain habitat in late winter and early spring and drawing water off the floodplain in late spring may increase spawning habitat for native fish such as Sacramento splittail while reducing the period of time that floodplains are suitable for spawning by non-native centrarchids.

Under current conditions, flows in the mainstem San Joaquin River are extremely reduced from historical conditions, which has drastically altered fish communities in the area and has likely improved habitat for non-native species while reducing habitat for native species. The non-native fish species that are currently most common in the mainstem San Joaquin River include several with the ability to tolerate very poor water quality, including common carp, red shiner, fathead minnow, inland silverside, and threadfin shad. Red shiners and inland silversides can be extremely abundant in shallow habitats and may be important predators on Sacramento splittail eggs and larvae and compete for food with juveniles of native fish species. Increasing flows and improving water quality in the mainstem San Joaquin River may actually improve habitat for non-native centrarchids that are currently more abundant in the lower reaches of the San Joaquin's major tributaries.

Many non-native fish are habitat generalists or have habitat requirements that closely overlap those of native fish in the deep-bodied fish assemblage. Reducing the availability of certain habitat types used by non-native species may also reduce habitat for the native resident fish species that have most declined in abundance and distribution. Measures that focus on flows that give a competitive edge to native fish or that reduce the distribution of non-native fish by reducing spring and summer water temperatures may be more successful at reducing negative impacts of non-native fish while maintaining native fish populations.

Populations of certain native fish species may be more difficult to enhance than others because they appear particularly vulnerable to negative interactions with non-native fish species. Certain species, such as Sacramento perch, appear to have declined primarily because of competition with or predation by non-native species. These species may require habitats that are spatially or temporally more isolated from non-native fish in order to thrive. Measures designed to increase habitat segregation between these species and non-native species may increase the abundance and distribution of native species.

Habitat availability and the effects of non-native species may not be the most important factors controlling populations of some native species. Factors such as poor water quality, pumping mortality, and entrainment into unscreened diversions may also reduce the abundance and distribution of fish species. For example, selenium may be affecting reproductive success of Sacramento splittail, which feed on *Potamocorbula* clams that bioaccumulate toxins (P. B. Moyle, pers. comm., 2002). Little is known regarding the effects of non-native aquatic plants and other organisms on native fish species.

Conditions favorable for producing strong year-classes of native fish species should occur at least once every 3 to 5 years for each to ensure long-term persistence of their populations in the study area. Most of the native resident fish that have been declining are long-lived species that can persist through years of unfavorable conditions, as long as years with favorable spawning and rearing conditions occur with enough regularity for them to persist. The strategies were evaluated in terms of their expected potential to provide each species with occasional years of high recruitment.

3.4.4 Approach used to develop restoration strategies to benefit native fish

For evaluating how strategies might affect native resident fish populations, we chose to select a set of "analysis species" to represent the habitat needs of the full complement of native species, instead of attempting to evaluate effects on each and every species. Restoration strategy measures designed for enhancing native resident fish populations focus on fulfilling the habitat requirements of native analysis species and reducing the abundance and distribution of non-native analysis species. By providing key habitat components for a set of carefully selected analysis species, the restoration strategies should be providing conditions that promote the persistence of all of the native fish species.

The life histories and habitat requirements of all native resident fish species were summarized in Appendix B of the Background Report (McBain and Trush 2002) and subsequently evaluated for similarities and differences between species. A set of criteria was used to determine which native fish species may be the most sensitive to changes in habitat from historical conditions. Analysis species selected met at least three of these criteria (Table 3.4-1). For each species, information was compiled on (1) key habitats and habitat requirements for important life stages, (2) timing of important life history events, (3) temperature requirements for spawning and other potentially important life stages, and (4) key interactions with non-native species that may limit native species populations. Some native fish species in the San Joaquin River basin appear to be relatively resilient to the habitat changes that have occurred and to the presence of non-native species. Species that fall into this category include Sacramento sucker and Sacramento blackfish. These fish were not included as analysis species because they are expected to benefit from any restoration measures that are implemented in the basin. Resident rainbow trout were excluded due to uncertainty about the origins of the population downstream of Friant Dam. White sturgeon were considered, but excluded because it is unlikely that they occurred in large numbers in the project area under historical conditions and because it would be very difficult to restore populations in the mainstem San Joaquin River (P. B. Moyle, pers. comm., 2002). The following species were selected as native analysis species: Pacific lamprey, Kern brook lamprey, Sacramento pikeminnow, hardhead, Sacramento splittail, hitch, tule perch, and Sacramento perch.

Table 3.4-1. Criteria used in selection of analysis species and results for selected analysis species.

CRITERIA	NATIVE FISH ANALYSIS SPECIES (X = species meets criteria; ? = likely that species meets criteria)						
	Pacific Lamprey	Sacramento Pikeminnow	Hardhead	Sacramento Splittail	Hitch	Tule Perch	Sacramento Perch
Species that have been extirpated in the San Joaquin River							X
Species with special status under the federal or state Endangered Species Act				?			
Species suspected to have substantially declined from their former distribution and abundance in the project area	?	?	X	X	X	X	X
Species that currently occur as disjunct populations or that may be vulnerable to habitat fragmentation and isolation					X	X	X
Species that may be particularly affected by physical or chemical barriers to freshwater movements and migrations (e.g., between mainstem and tributaries or between mainstem habitats used by different life history stages)	X	X	X		X		
Species suspected of being negatively affected by loss of floodplain and lake habitats				X	X	X	X
Species suspected of being negatively affected by loss of riparian and wetland habitats		X				X	
Species that may be particularly sensitive to changes in water temperatures and seasonal temperature regimes	X					X	
Species that may be relatively intolerant of contaminants or that tend to be found in areas where concentrations of contaminants are high	X			X			
Species likely to be adversely affected by interactions with introduced species	X	X	X	X	X		X
Species that may be negatively affected by changes in flow regimes, particularly the loss of high spring flows							
Species that may be particularly susceptible to entrainment at agricultural diversions and pumps	X	?		X			

By addressing the needs of a set of species that encompass a wide variety of life history strategies and habitat requirements, we hoped to address the needs of the remaining species, acknowledging that the use of "umbrella" species may overlook the needs of some, especially those for which there is little available information. Such a strategy has certain limitations. For example, it is not likely that each strategy will provide equal benefits for native resident fish; however, it will allow us to assess which restoration measures might come closest to providing for the needs of most native fish species and to design further measures to address those that appear to fall through the cracks.

Other potential methods of addressing the needs of species in a freshwater fish community that were considered include the use of habitat-use guilds or key habitats. Because several native fish in the San Joaquin basin are anadromous, and others use different habitats at different life stages, habitat connectivity is crucial for maintaining native fish populations. Another consideration that may not be adequately addressed by a key habitat approach is that spatial and temporal differences in water temperatures may have substantial effects on habitat quality for native and non-native species.

The habitat requirements of key life history stages of the native fish analysis species were compared to determine non-overlapping habitat needs that might not be addressed by strategies designed to benefit the other species. For fish species that appeared to have habitat requirements that would require instream flows or restoration of habitat components over and above those being proposed for anadromous salmonid or riparian restoration, we tried to develop measures to fulfill the needs of these species. Many uncertainties remain due to our lack of knowledge about native resident fish species in the San Joaquin River. Our analysis focused on what we knew regarding habitat and temperature preferences during critical life history stages such as spawning and early rearing.

To develop restoration strategy measures that enhance native fish populations, we have included measures aimed at reducing negative interactions between non-native and native species by reducing the abundance and distribution of non-native species that appear to be strong interactors in the fish communities of the San Joaquin River. Some non-native fish species, especially omnivores and detritivores, may have relatively little effect on native aquatic species. Certain non-native species may be providing benefits to native fish and aquatic communities in ways that are not immediately evident. Some non-native fish species may feed on introduced plants or invertebrates (e.g., non-native bivalves and crayfish) that may themselves alter aquatic habitats and food webs. Others, such as smaller introduced cyprinids, may provide non-native black bass and other piscivorous fish with alternative prey and thereby buffer predation on native species. Invasions of piscivorous fish may have the greatest effects on native fish communities (Moyle and Light 1996).

3.4.5 Restoration strategy considerations for analysis species

The following sections describe habitat requirements for analysis species that likely need to be addressed to achieve the vision of maintaining and restoring populations of native fish species in the project area. These habitat requirements were considered when developing specific restoration strategy components to benefit native fish populations. More detailed information on habitat requirements for all species likely to be found in the project area are found in Appendix B of the Background Report.

3.4.5.1 Habitat requirements held in common by several analysis species

The following summarizes habitat requirements held in common by several analysis species. The lack of certain habitats, habitat characteristics, or habitat connectivity between important habitats used by different life stages in the project area may severely limit the abundance and distribution of several native species.

Deep, low-velocity habitats for adults

Adults of many native resident fish require deep, slow habitats such as sluggish mainstem runs, deep main-channel pools, backwaters, oxbow lakes, and sloughs. Several species appear to require summer water temperatures between 68° and 82.4°F (20° and 28°C) in order to thrive. These species include Sacramento pikeminnow, hardhead, and hitch. Sacramento perch may also use deeper warmwater habitats if cover from vegetation, large woody debris, or turbidity is available.

Habitat connectivity for instream movements and migrations
Several species make upstream spawning migrations to riffle spawning habitats in tributaries or upper mainstem reaches when flows increase with spring runoff, primarily from February through April. Others, such as Sacramento splittail, move upstream from Delta habitats to spawn in inundated floodplains. Analysis species that may require habitat connectivity in the spring to successfully complete their life cycles include Pacific lamprey, Sacramento pikeminnow, hardhead, Sacramento splittail, and hitch. Hardhead exhibit relatively poor swimming performance at low temperatures, and water velocity may act as a barrier to their upstream movements (Myrick 1996, as cited in Moyle 2002).

Gravel riffles for spawning
Pacific lamprey and other native lamprey species (Kern brook lamprey, river lamprey, and western brook lamprey) build nests in gravel or gravel-sand riffles. Several other native resident species broadcast spawn over riffle habitats, including Sacramento pikeminnow, hardhead, Sacramento sucker, and hitch. All of these species spawn in the spring from February through May at temperatures of about 53.6−64.4°F (12−18°C). Some species may spawn into the summer months where temperatures remain suitable.

Shallow areas with cover for rearing
Many native resident fish species require shallow areas with dense emergent or aquatic vegetation for larval and early juvenile rearing, including Sacramento pikeminnow, hardhead, hitch, Sacramento splittail, and Sacramento perch. Shallow areas with dense vegetation provide hiding cover from both avian and larger fish predators. Most species spawn in the spring; therefore, early rearing habitat would likely be provided by inundation of channel margins and floodplain habitat during snowmelt runoff under unimpaired conditions. Extreme flow fluctuations or rapid downramping of flows during the spring or summer may result in stranding mortality of fish rearing in these shallow habitats.

3.4.5.2 Pacific lamprey and Kern brook lamprey

Three lamprey species known to occur in the mainstem San Joaquin River downstream of Friant Dam have recently been petitioned for listing under the federal Endangered Species Act due to substantial declines in their abundance—Pacific lamprey (anadromous), river lamprey (anadromous), and Kern brook lamprey (resident) (Klamath Siskiyou Wildlands Center et al. 2003). It is not known whether western brook lamprey currently exist in the San Joaquin River. For the sake of developing restoration strategies for native resident fish, it was assumed that providing for the habitat needs of Pacific lamprey and Kern brook lamprey will be sufficient for protecting populations of all lamprey species that may occur in the project area.

Pacific lamprey are an anadromous species that rear for 4 to 7 years before outmigrating to the ocean as subadults. Pacific lamprey appear to prefer rearing temperatures below 68°F (20°C) (BioAnalysts 2000), and temperatures >82.4°F (28°C) result in mortality of ammocoetes (van de Wetering and Ewing 1999). When abundant, outmigrating Pacific lamprey may act to buffer predation on juvenile and smolt salmon because they are easier to capture than salmonids (Close et al. 2002).

The Kern brook lamprey is a resident lamprey species whose populations are believed to be thinly scattered throughout the San Joaquin River basin and appear to be isolated from one another (Moyle 2002). All known populations except for one are located below dams where flow regulation may dewater rearing habitat and result in mortality of rearing ammocoetes. Moyle (2002) notes that ammocoetes may also be transported to habitat “sinks” such as the Friant-Kern siphons. The Kern brook lamprey is believed to be at risk of being locally extirpated where these isolated populations occur.

All lamprey ammocoetes rear burrowed in fine sediments in low-velocity habitats for several years before metamorphosing to the subadult stage. Low-velocity areas along the margins of runs may provide some habitat for ammocoetes where backwaters, pool eddies, or other shallow areas are not available or are not inundated year-round (P. B. Moyle, pers. comm., 2002). The long freshwater rearing period required by lamprey before metamorphosis makes them more vulnerable to episodic mortality factors than salmonids or other native fish. Such factors include dewatering of areas used as rearing habitat by rapid flow fluctuations or downramping, contaminants, dredging, and streambed scouring by high flows. River channelization increases stream velocity and reduces the amount of rearing habitat available for ammocoetes (Close et al. 2002). Lamprey ammocoetes may pass through screens designed to prevent juvenile salmon from passage. Transport into irrigation ditches is likely to result in mortality when ditches are drained and there is no passage back to a natural waterway.

Adult Pacific lamprey returning from the ocean to spawn require suitable migration corridors. Adult upstream migration of Pacific lamprey into spawning streams in California may occur as early as January and February, but primarily occurs from early March to late June during high flows (Moyle 2002). Nests are constructed by Pacific lamprey in the spring in gravel or gravel-sand riffles at temperatures of 53.6−64.4°F (12−18°C) (Moyle 2002). Eggs hatch in two to three weeks; larval ammocoetes spend another two to three weeks in the gravels before emerging and rising into the current to drift downstream and settle into slow backwater areas (Pletcher 1963). During the ammocoete stage, larvae may periodically move and relocate in response to changing water levels, channel adjustments, or substrate movements (ULEP 1998). This generally results in a gradual downstream movement that may lead to higher densities in downstream reaches (Richards 1980). Downstream migration of young adults on their way to the sea may occur from winter through spring during high flows.

The following are important habitat management considerations for Pacific lamprey and Kern brook lamprey:

- managing spring flows to provide suitable upstream migration corridors and spawning habitat,
- managing flows to reduce dewatering of lamprey nests before ammocoete emergence, and
- maintaining suitable ammocoete rearing habitat year-round in upstream reaches.

An important factor potentially limiting lamprey populations that may not be addressed by restoration strategies is their use of low-gradient stream reaches at lower elevations, where human disturbance and habitat degradation is often highest. Ammocoetes may be vulnerable to bioaccumulation of pollutants as a result of spending several years as filter feeders in stream sediments. Moyle (2002) noted that Pacific lamprey are usually absent from highly altered or polluted streams.

3.4.5.3 Sacramento pikeminnow

Adult Sacramento pikeminnow inhabit deep pools and slow runs with cover where water temperatures are about 68.0−82.4°F (20−28°C) in the summer months. Upstream movements to suitable spawning habitat occurs from March through May. Broadcast spawning takes place over gravel riffles and may begin in late February through May, with peak spawning in March and

April. Spawning may continue into June and July in some areas. Young-of-the-year rear in shallow channel margin habitats and move into riffles and runs as they grow.

The following are important habitat management considerations for Sacramento pikeminnow:

- managing spring flows to provide suitable upstream migration and spawning habitat,
- inundating shallow rearing habitat in late spring and early summer, and
- regulating downramping in late spring to minimize stranding of young-of-the-year in shallow rearing habitat.

.

3.4.5.4 Hardhead

The general habitat requirements of hardhead are similar to those of Sacramento pikeminnow in several ways. Hardhead spawn in April and May and possibly into the summer in some areas. Although spawning has not been observed, they are believed to broadcast spawn over gravel in riffles, similarly to pikeminnow. They are also similar in that adult hardhead use deeper pool and open-water habitats, while young-of-the-year prefer shallower habitats where they are likely less vulnerable to fish predation. Hardhead also make upstream migrations to suitable spawning areas and therefore require habitat connectivity between adult and spawning habitat in the spring. The species is most often found where summer water temperatures are at least 68°F (20°C) for extended periods of time. For the purposes of this analysis, the above habitat requirements will be assumed to be the same as for Sacramento pikeminnow.

Hardhead appear to have much more restricted microhabitat preferences than Sacramento pikeminnow, being found "only in the sections of large, warm streams that contain deep, rock-bottomed pools" (Moyle et al. 1982). Hardhead distribution may also be limited by low dissolved oxygen concentrations at higher temperatures (Cech et al. 1990, as cited in Moyle 2002). High water velocities may act as a barrier to upstream movements of hardhead at low temperatures, when their swimming abilities are relatively poor (Myrick 1996, as cited in Moyle 2002).

The following are important habitat management considerations for hardhead:

- managing spring flows to provide suitable upstream migration and spawning habitat, and
- maintaining or enhancing deep rocky pool habitat for juveniles and adults.

3.4.5.5 Sacramento splittail

The loss of large lake and floodplain spawning habitat is believed to have been a major contributor to decline of this species in the San Joaquin River basin. Adult Sacramento splittail make upstream spawning migrations from January through April. Adult splittail may require a period of time to congregate and feed on the floodplain prior to spawning. Spawning occurs from February through May, with peak spawning generally occurring in March and April. Spawning is triggered when temperatures reach 57.2−66.2°F (14−19°C), but spawning appears to occur primarily where water temperatures are less than 59° (15°C) (Bailey et al. 1999, Moyle et al. 2001). At least a month of rearing on the inundated floodplain appears necessary for development of a strong year-class (Sommer et al. 1997). Following spawning, splittail are expected to move downstream out of the project area into brackish habitats.

The following are important habitat management considerations for Sacramento splittail:

- managing spring flows to inundate floodplain surfaces from February through at least the end of April for spawning, and
- managing flows or modifying floodplain surfaces to reduce stranding of young-of-the-year

splittail on floodplains.

3.4.5.6 Hitch

Populations of hitch in the San Joaquin River basin appear to be declining and increasingly isolated from one another (Moyle 2002). Hitch appear to have been extirpated from some areas of the San Joaquin River within the past decade (Moyle 2002). They generally make upstream migrations to spawn in mainstem or tributary riffles from March to June when flows increase in the spring, at temperatures from 57.2 to 64.4°F (14 to 18°C) (Moyle 2002). Factors potentially contributing to their decline include loss of spring spawning flows, loss of summer rearing and holding habitat, increased pollution, and predation by non-native species (Moyle 2002). Hitch tolerate the highest temperatures of any Central Valley native fish, preferring temperatures between 80.6° and 82.4°F (27° and 28°C).

The following are important habitat management considerations for hitch:

- managing spring flows to provide suitable upstream migration and spawning habitat, and
- creating additional spawning habitat on floodplains, where feasible.

3.4.5.7 Tule perch

Tule perch inhabit slow-moving reaches that have shoreline areas with cover provided by dense aquatic or emergent vegetation, overhanging riparian vegetation, or other complex structure. They bear live young and appear to be less vulnerable to predation by non-native species than other native resident fish. They prefer cooler water temperatures than the other analysis species, being rarely found in streams where temperatures exceed 77°F (25°C) for extended periods and generally preferring temperatures <71.6°F (22°C). Poor water quality, low dissolved oxygen, and contaminants may limit their distribution.

The following are important habitat management considerations for tule perch:

- maintaining and restoring riparian habitat and shoreline areas with complex cover, and
- maintaining suitable temperatures in areas with dense riparian vegetation.

3.4.5.8 Sacramento perch

Sacramento perch tolerate high water temperature (preferring temperatures of 77 to 82.4°F [25 to 28°C]), high turbidity, high salinity, and high alkalinity. They may be best able to persist in habitats where non-native centrarchids are excluded by high alkalinity, due to high overlap in habitat preferences and competition for food. The species appears to compete for food and space most strongly with bluegill and black crappie (Moyle 2002). Adults defend nests and larvae, but eggs and larvae are nonetheless vulnerable to predation. For spawning, Sacramento perch require shallow areas (8−20 in [20−50 cm] in depth) with dense aquatic vegetation that are inundated in the spring at temperatures from 64.4 to 84.2°F (18 to 29°C) (P. Crain, University of California, unpubl. data, 1998, as cited in Moyle 2002). Spawning occurs from late March through early August, generally peaking in late May and early June. Adults prefer slow-moving reaches with aquatic vegetation, but highly turbid reaches without cover may also be suitable (Moyle 2002). Little is known regarding their early life history stages and whether physical or chemical factors may limit their survival (Moyle et al. 2002); however, efforts to answer these questions may be helpful for developing strategies for their reintroduction to the San Joaquin River system.

The following are important habitat management considerations for Sacramento perch:

- creating opportunities for reintroducing Sacramento perch into habitats where they can reproduce in relative isolation from non-native fish species and act as source populations for seeding mainstem habitats, and
- managing flows to reduce the abundance and distribution of non-native centrarchids.

Table 3.4-2 summarizes the habitat requirements of native fish analysis species.

Table 3.4-2. Habitat requirements of native fish analysis species.

HABITAT REQUIREMENTS SHARED BY MORE THAN ONE SPECIES		
HABITAT REQUIREMENT	**SUITABLE TEMPERATURE RANGE**	**REQUIREMENTS FOR RELEVANT ANALYSIS SPECIES**
deep (>3 ft [1 m]) habitats (e.g., deep runs, pools, sloughs) with warm summer temperatures for adults	68.0° to 82.4°F (20° to 28°C)	C **Sacramento pikeminnow** are most abundant where summer temperatures are >68°F (20°C) for extended periods of time C **hardhead** most often occur in streams with summer temperatures >68°F (20°C) C **hitch** tolerate extremely high temperatures and actively select temperatures >77°F (25°C)
longitudinal habitat connectivity for seasonal spawning migrations in late winter and spring, especially March and April	53.6° to 64.4°F (12° to 18°C)	C **Pacific lamprey** upstream migration occurs during high flows and may begin in ***January and February***, but primarily occurs from ***early March to late June***; downstream migration most likely occurs in winter and spring during high flow events C **Sacramento pikeminnow** move upstream to spawn from ***March through May*** C **hardhead** move upstream to spawn in ***April and May*** C **Sacramento splittail** move upstream to spawn from ***January through April*** C **hitch** move upstream to spawn with spring high flows in ***March and April***
gravel riffles suitable for spawning in spring	53.6° to 64.4°F (12° to 18°C)	C **Pacific lamprey** spawn in gravel or gravel and sand substrates (generally smaller than those preferred by chinook salmon) in spring at temperatures of 53.6−64.4°F (12−18°C) C **Sacramento pikeminnow** spawn from late February through May, with peak spawning in March and April C **hardhead** spawn in April and May and possibly into the summer months C **hitch** spawn in clean, fine to medium size gravel during high spring flows from March to June at temperatures from 57.2−64.4°F (14−18°C)
shallow (0-20 in [0-50 cm]) rearing habitat, with cover provided by aquatic, emergent, or annual vegetation or turbidity, and warm summer temperatures [late spring through summer]	68.0° to 82.4°F (20° to 28°C)	The following species share this habitat requirement: C **Sacramento pikeminnow** C **hardhead** C **hitch** C **Sacramento splittail** C **Sacramento perch**
SPECIES-SPECIFIC NON-OVERLAPPING HABITAT REQUIREMENTS		
Pacific lamprey	year-round temperatures <77°F (25°C), but preferably <68°F (20°C)	shallow, low-velocity, flowing-water habitats (e.g., backwaters, sloughs, channel margins) with mud or other fine substrate that remain inundated year-round
Hardhead	summer temperatures >68°F (20°C), but more preferably >24°C (75.2°F)	deep (>2.5 ft [0.75 m]) rock-bottomed pools with and relatively high dissolved oxygen concentrations
Sacramento splittail	temperatures ≥57.2−66.2°F (14-19°C); but preferably <59°F (15°) for spawning	floodplains inundated at depths from 1.6 to 6 ft (0.5 to 2 m) for a minimum of 60 days within the period from February through May
Tule perch	summer temperatures <71.6°F (22°C)	deeper low-velocity habitats with shoreline areas having dense cover from aquatic vegetation, overhanging riparian vegetation, or complex large woody debris
Sacramento perch	summer temperatures from 64.4° to 82.4°F (18° to 28°C)	low-velocity habitats with cover provided by aquatic or emergent vegetation or turbidity, and shallow areas (8-20 in [20-50 cm]) with dense aquatic vegetation for spawning inundated for at least 30 days during the period from April through July (peak spawning generally occurs in late May and early June)

3.4.6 Restoration strategy measures anticipated to benefit native resident fish

3.4.6.1 Inundating floodplains in the spring

One of the primary restoration measures intended to support the reintroduction of chinook salmon to the San Joaquin River is the restoration of spring high flows and floodplain inundation to the riverine ecosystem. The strategy includes inundating already existing floodplains, as well as designing and creating new floodplains in Reach 4B and the Mendota Bypass reach. These measures are likely to improve conditions for native resident fish while reducing habitat quantity and quality for non-native fish species. Sacramento splittail, Sacramento blackfish, and Sacramento perch are all adapted to spawning on floodplains in the spring. Inundating floodplains during the natural spring run-off period should promote spawning by native resident fish and provide larvae and early life history stages with high-quality rearing habitat. Drawing water off of the floodplains by late spring or summer may reduce the amount of time that non-native centrarchids such as bass and sunfish can successfully spawn on the floodplains. Engineered floodplains can also be designed to reduce the potential for stranding during the period when downramping occurs.

Most mortality of both native and non-native resident fish occurs during the critical egg and young-of-the-year stages, when vulnerability to predation is extremely high. Providing suitable spawning and rearing habitat early in the spring for native resident fish may increase survival during the critical first few months when predation mortality may be highest. Shallow areas with dense vegetation would provide warm temperatures for fast growth, cover from predation, and may discourage larger piscivorous fish from moving onto the floodplains from the main channel. Because many of the non-native resident species spawn later in the spring or at warmer temperatures than native species, promoting early spring spawning on floodplains by native species may actually increase predation by juvenile native fish on the larvae and fry of later-spawning centrarchids. Common carp are likely to use floodplains for spawning; however, their presence may not substantially reduce habitat quality for native fish species. Other non-native resident fish species that may use floodplains include largemouth bass, sunfish (*Lepomis* spp.), crappies (*Pomoxis* spp.), inland silverside, red shiner, and threadfin shad. Largemouth bass generally spawn at depths from 12 to 40 in (30 to 100 cm), but prefer to spawn at depths >18 in (45 cm); it may be possible to discourage some spawning by bass by manipulating the availability of their preferred depths when temperatures are suitable for spawning (largemouth bass most often spawn at temperatures between 61° and 72°F [16° and 22°C]). However, the spawning habitat preferences of largemouth bass overlap to a large degree with those of Sacramento perch, which could also benefit from floodplain habitat enhancement if they become reestablished in the basin.

Floodplains in Reach 4B and the Mendota Bypass reach could be used to provide high-quality Sacramento splittail spawning and rearing habitat in some water-years. These floodplains could be designed to test how various characteristics affect splittail use and year-class strength as part of an adaptive management program. Parameters that could be tested include: (1) inundation depth, (2) inundation duration, (3) inundation timing, (4) water velocities on the floodplain surface, (5) temperature, (6) stranding effects, and (7) substrate and vegetative cover characteristics. The results of such investigations could be used to modify areas to further improve habitat for splittail or to guide restoration of floodplains in other areas. Such floodplains are expected to benefit both splittail and rearing chinook salmon. Juvenile chinook move onto the flooded Yolo Bypass in January and February and move off in March when temperatures are increasing. Splittail move onto floodplains in February as temperatures increase to 57.2−66.2°F

(14−19°C) and generally spawn where temperatures are generally less than 59°F (15°C) (Moyle et al. 2001). Splittail tend to depart the Yolo Bypass for cooler habitats when temperatures approach 68°F (20°C). Juvenile chinook salmon may be able to remain on the floodplains at these temperatures as long as nighttime temperatures are below about 64°F (18°C) (P. B. Moyle, pers. comm., 2002). Sacramento blackfish would be expected to spawn later in the season than splittail; in Clear Lake they are observed to spawn from April to July at temperatures from 54° to 75°F (12° to 23°C) (Moyle 2002).

3.4.6.2 Creating perennial wetlands on floodplains

Reconstructing perennial wetlands within natural and engineered floodplains would restore naturally occurring habitats that may be used by certain native fish species such as Sacramento blackfish and hitch. Both of these species are capable of surviving in small ponds less than a half-acre in size (P. B. Moyle, pers. comm., 2002). Pools that are hydrologically connected with the main channel appear to support non-native fish species better than those that are completely disconnected when flows recede (P. B. Moyle, pers. comm., 2002). Sacramento blackfish are found in areas where summer water temperatures exceed 86°F (30°C) and dissolved oxygen concentrations are low (Moyle 2002); upper lethal temperatures for blackfish may be as high as 98.6°F (37°C) (Knight 1985, as cited in Moyle 2002). In lakes and ponds, blackfish, which are filter-feeding herbivores, may feed on plankton suspended in the water column as well as on soft bottom material that is rich in organic matter and small invertebrates (Moyle 2002). Hitch are also planktivores that feed on filamentous algae and aquatic and terrestrial insects (M. Dege, University of California, Davis, unpubl. data, 1996, as cited in Moyle 2002). Hitch tolerate the highest temperatures of any Central Valley native fish, selecting temperatures between 80.6°F and 82.4°F (27°C and 28°C) and withstanding temperatures up to 100.4°F (38°C) for short periods of time (Knight 1985, as cited in Moyle 2002). They have also been found in water with salinities as high as 9 ppt (J. J. Smith, California State University, San Jose, pers. comm., as cited in Moyle 2002). Ponds and wetlands on floodplains may also be colonized by non-native fish species that tolerate high water temperatures and low dissolved oxygen, such as largemouth bass and carp. Factors that may influence colonization by non-native fish may include when and how often the habitats are hydrologically connected to the San Joaquin River. Monitoring and adaptive management of floodplain wetlands may be useful for attempting to resolve such uncertainties and maintaining these wetlands and ponds as pockets of habitat for native fish.

3.4.6.3 Creating opportunities for Sacramento perch reintroduction

Perennial wetlands and small floodplain ponds and lakes could be restored with the intention of creating opportunities for reintroducing Sacramento perch to the San Joaquin basin. Some perennial wetlands on floodplains could be designed to provide high-quality habitat for Sacramento perch where interactions with certain non-native fish species could be controlled through isolation, periodic dewatering and removal of non-natives, or other means. Ponds for experimental perch reintroduction should first be constructed where they can be easily maintained. If they are flooded only when flows are high and temperatures cool enough, and if water is drained off before temperatures warm too much, colonization by non-native fish species may not pose a big problem. Floodplain ponds that are hydrologically connected to the mainstem channel at high flows can also provide a mechanism for seeding mainstem habitats with Sacramento perch. Floodplain ponds and depressions would also be expected to provide high-quality feeding habitat for Sacramento splittail, which have been found to congregate in pools in the Yolo Bypass when zooplankton blooms occur in them (P. B. Moyle, pers. comm., 2002). Existing aquaculture ponds upstream of Mendota Pool along RM 246 may be able to be redesigned to provide opportunities for experimental Sacramento perch reintroductions to the San Joaquin basin.

Floodplain ponds designed for Sacramento perch would need to consider their specific habitat requirements and tolerances. Sacramento perch prefer temperatures from 77° to 82.4°F (25° to 28°C) and can tolerate high salinity, alkalinity, and turbidity (Moyle 2002). Their ability to tolerate high alkalinities may make it possible for them to persist in some areas because of reduced interactions with non-native species that do not share this tolerance. They can successfully survive and reproduce in ponds as small as 200 ft^2 (P. B. Moyle, pers. comm., 2002). Floodplain ponds created for Sacramento perch and other native fish should be at least 6 ft (2 m) deep to provide cover from avian predation and refuge from temperature extremes (P. B. Moyle, pers. comm., 2002). Aquatic and emergent vegetation would be important as cover from predation, especially for larvae and young-of-the-year fish, although turbid water may afford similar cover (Moyle 2002). Tule marsh can provide suitable habitat for perch if open water is available. In small lakes and ponds, chironomids appear to remain important in the diet of even large adult Sacramento perch, with small crustaceans and fish of secondary importance (Moyle 2002). Occasional removal of excess aquatic and emergent vegetation may be required to maintain open water if habitats become choked with vegetation.

Monitoring and adaptive management of floodplain habitats designed for Sacramento perch would improve the likelihood that isolated populations could be successfully established and that such populations might someday act as source populations for recruiting individuals to mainstem San Joaquin River habitats in the future. Several variables could be manipulated to evaluate how they affect Sacramento perch survival and reproduction in floodplain habitats and their ability to withstand potential periodic invasion by non-native fish. Some of the variables that could be experimented with include depth, area/size of open-water habitat, percent cover by submergent and emergent vegetation, and degree of hydrologic connectivity with main channel.

3.4.6.4 Flow management to reduce abundance and distribution of non-native fishes

Although non-native species may be here to stay, it may be possible to reduce their negative impacts on native fish communities so that most, if not all, of the native species can continue to maintain viable populations. Managing flows in the San Joaquin River to more closely resemble the naturally variable hydrograph may give native fish species a competitive edge over non-native species. Certain flow-related measures may only be feasible to implement in wetter water years due to conflicting needs for water in the basin. However, the long life span of many native fish species and the fact that they have evolved to withstand periods of prolonged drought, floods, large seasonal and interannual variations in instream flows, and other disturbances increases the likelihood that such measures would be successful.

High spring flows will reduce temperatures in the main channel, which will improve rearing habitat quality for juvenile salmonids. These same flows should provide suitable riffle spawning habitat for native fish species in Reach 1 during the spring when these species spawn. Flows that inundate shallow, vegetated channel margin habitat will also create valuable early rearing habitat for these species. Native species that may benefit from these habitat improvements include Pacific lamprey, Sacramento pikeminnow, hardhead, and Sacramento sucker. High spring flows that reduce temperatures in the main channel should reduce the area suitable for the spawning and rearing of centrarchids, as well as the duration of the season that spawning of these species can successfully occur. Managing flows to reflect different water-year types should also promote native resident fish over non-native resident fish. Within the group of native resident species, between-year fluctuations in environmental conditions may be critical for maintaining the diversity of species that are present in the system. Since many species are long-lived, they can persist during periods when conditions may be more suitable for other members of the community.

Flow fluctuations or high flows timed during late spring or early summer may delay or disrupt spawning by some non-native species such as largemouth bass and thus reduce the duration of their spawning season. Repeated flow pulses in wet years may reduce spawning success and larval survival of non-native centrarchids for a large portion of the season. Even if such measures are only implemented in wet years, they may benefit native fish species through reducing populations of resident centrarchids. There are many uncertainties regarding the potential for such measures to succeed; a monitoring and adaptive management program would be valuable for evaluating flow-management techniques for reducing spawning success of non-native species.

3.4.6.5 Establishing a native fish community in Mendota Pool

It may be possible to establish a native fish community in Mendota Pool and to use this as a source of fish for seeding floodplain ponds and other newly restored habitats. Because Mendota Pool is periodically drained, it would be possible to physically remove many non-native fish and restock the reservoir with native fish. Restoring wetland and riparian habitats on the banks of Mendota Pool could increase its habitat value for native fish. Native resident fish that could be introduced include Sacramento perch, hitch, Sacramento blackfish, prickly sculpin, and tule perch (if temperature and water quality are suitable). Larvae of non-native fish species would continue to be recruited into Mendota Pool, but predation by established populations of native fishes might prevent successful establishment of non-native populations (P. B. Moyle, pers. comm., 2002). However, periodic draining of the water body may be necessary to ensure that non-native fish do not become established. Mendota Pool could also provide an opportunity to educate the public about native fishes and their ecology. Public education is very important for protecting native fishes and their habitats and may increase support for enhancement measures.

3.4.6.6 Improving habitat connectivity

Under current conditions, physical barriers, water velocities, insufficient flows, high water temperatures, contaminants, and low dissolved oxygen may prevent or impede upstream movements of native resident, as well as anadromous, fish species. In addition, entrainment of eggs, larval fish, and juvenile fish into screened and unscreened agricultural diversions, and Delta pumps, may affect habitat connectivity for juvenile fish dispersing to appropriate rearing habitats.