5

Fisheries

5 FISHERIES

This chapter summarizes the historical and current conditions for fisheries in lower Putah Creek. It discusses special-status fish species, introduced and invasive fish and invertebrates, the history of fisheries and stream conditions in lower Putah Creek from the pre-Euro-American settlement period to present, and analyses of spawning habitat and shaded riverine aquatic (SRA) cover habitat in lower Putah Creek. Chapter 4, "Geomorphology, Hydrology, and Water Quality," includes discussions of environmental factors relevant to fisheries (e.g., temperature, mercury). Appendix F provides a list of the common and scientific names of fish species known from lower Putah Creek that are discussed in this chapter.

The primary sources of information for this chapter were both published and unpublished reports on the fish, fisheries, ecology, and natural history of the Putah Creek watershed, along with information provided by specialists knowledgeable on lower Putah Creek fisheries. The primary sources of information were Dr. Peter Moyle, Patrick Crain, Thomas R. Payne and Associates, Dr. Michael Marchetti, Katie Small, Gus Yates, and Ken Davis. Information from Dr. Moyle included studies, presentations, personal communications, and the book, *Inland Fishes of California – Revised and Expanded* (Moyle 2002a). Dr. Michael Marchetti conducted dissertation research on Putah Creek, culminating in scientific papers used in compiling this report. Mr. Yates' report, *Gravel and Temperature Surveys of Lower Putah Creek* (2003), funded by the CALFED Bay-Delta Authority, was used to describe the existing channel substrate and potential spawning habitat conditions in lower Putah Creek. Dr. Moyle, Patrick Crain, and Katie Small also provided analyses and preliminary interpretations of fish sampling data collected between 1990 and 2002 by Thomas R. Payne and Associates fish biologists and UC Davis fish biologists. Ken Davis supplied information on the locations of New Zealand mud snail infestations, an invasive aquatic organism discovered in Putah Creek for the first time in October 2003. The methods used for assessing SRA habitat cover are provided along with the results of that assessment.

5.1 SPECIAL-STATUS FISH SPECIES

This subsection briefly describes native special-status fish species and regulatory requirements pertaining to fish. Laws and regulations pertaining to fisheries are provided in Appendix H, "Permitting, and Regulatory Compliance."

Special-status species include species in the following categories: species listed or proposed for listing as Threatened or Endangered under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA); species considered as candidates for listing as Threatened or Endangered under ESA or CESA; species identified by DFG as Species of Special Concern; and species that are fully protected under the California Fish and Game Code.

A total of seven special-status fish species occur or have the potential to occur in lower Putah Creek and are described below. Of the seven species, only Steelhead-Central Valley

Evolutionarily Significant Unit (ESU) is listed as a federally Threatened species. The USFWS de-listed Sacramento splittail from it's federally Threatened status on September 22, 2003. NMFS determined that listing is not warranted for Central Valley fall/late fall-run chinook salmon. However, it is still designated as a candidate for listing because of concerns over specific risk factors. The four remaining species (Pacific lamprey, Sacramento-San Joaquin roach, hardhead, and Sacramento perch) are considered Species of Special Concern by DFG and/or Federal Species of Concern by NMFS or USFWS. Brief descriptions follow for the special-status species with potential to occur in lower Putah Creek.

5.1.1 STEELHEAD

The Central Valley steelhead ESU (*Oncoryhnchus mykiss*) is a Federally threatened species. The Central Valley steelhead includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries (USBR and DWR 2003). Steelhead have a complex life history, including the capability to be anadromous or resident (called rainbow trout) (NMFS 2002 as cited in USBR and DWR 2003). Anadromous species spend most or a portion of their adult life in the ocean and then migrate back into freshwater to reproduce. Spawning and rearing habitat for steelhead typically occurs in perennial streams with clear, cool to cold, fast-flowing water with a high dissolved oxygen content and abundant gravels and riffles (Bovee 1978 as cited in USBR and CDWR 2003). After spending 1–4 years in the ocean, adult steelhead return to their home streams to spawn (Moyle 2002a). Migration into freshwater begins in August and peaks in September–October, after which the steelhead hold until flows are sufficiently high to enable migration into tributaries (Moyle 2002a). Spawning begins in late December and peaks in February–March (Busby et al. 1996). Steelhead eggs hatch in 3–4 weeks (at 50–59°F), and fry emerge from the gravel 2–3 weeks later (Moyle 2002a). After steelhead fry emerge from spawning gravels, they continue to grow and mature in freshwater for 1–3 years before emigrating to the ocean (Moyle 2002a). Unlike salmon, steelhead do not necessarily die after spawning and can spawn more than one time. In central California, most spawning steelhead are 3 years old, with one year spent in the ocean (Busby et al. 1996). Anadromous steelhead are considered to have historically spawned in the upper tributaries flowing into Putah Creek above the Berryessa Valley (now Lake Berryessa) but there have been no recently confirmed reports of anadromous steelhead in the creek. Migratory rainbow trout with a steelhead-like life history continue to spawn in the upper tributaries (Moyle, pers. comm., 2003).

5.1.2 CHINOOK SALMON

Central Valley fall/late fall-run chinook salmon ESU (*Oncoryhnchus tshawytscha*) is a Federal Candidate Species. Fall-run chinook salmon is the most widely distributed and most numerous run occurring in the Sacramento and San Joaquin rivers and their tributaries (USBR and DWR 2003). Chinook salmon is an anadromous fish species that requires cold, freshwater streams with suitable gravel for reproduction. After spending 2–4 years maturing in the ocean, chinook salmon return to their natal streams to spawn (Moyle 2002a). After spawning, eggs generally hatch in 6–12 weeks, and newly emerged larvae remain in the gravel for another 2–

4 weeks until the yolk is absorbed. Juveniles typically rear in fresh water for up to 5 months before migrating to sea. Unlike steelhead, adult chinook salmon die after spawning (Moyle 2002a). Chinook salmon have historically spawned in Putah Creek and, after decades of sparse occurrences, returned to spawn in larger numbers in lower Putah Creek in fall 2003. Descriptions of historic occurrences of salmon in lower Putah Creek and the recent (2003) historic run of salmon are provided in the subsections that follow.

5.1.3 SACRAMENTO SPLITTAIL

Sacramento splittail (*Pogonichthys macrolepidotus*) has been de-listed from its Federal Threatened status but remains a California Species of Special Concern. This large cyprinid (minnow family) is endemic to California and occurs in sloughs, lakes, and rivers of the Central Valley (Moyle 2002a). Sacramento splittail spawns on terrestrial vegetation and debris on floodplains inundated by high spring flows (Moyle 2002a). In wet years, Sacramento splittail are commonly found in the Putah Creek Sinks, in the region where Putah Creek crosses the Yolo Bypass, and the Bypass provides valuable spawning and rearing habitat for splittail (Sommer et al. 1997; 2001). In spring 2004, 24 juvenile splittail were caught in Putah Creek in the reach downstream of the County Road 106 crossing during surveys (Moyle, Crain, pers. comm., 2004).

5.1.4 PACIFIC LAMPREY

Pacific lamprey (*Lampetra tridentada*) is a Federal Species of Concern. Pacific lamprey is an anadromous species that occurs in tributaries from Japan to Alaska to Baja California and spawns in gravel substrate (Moyle 2002a). After spending up to perhaps 3–4 years in the ocean, adult Pacific lamprey move up into spawning streams in early March to late June, with some reports of upstream migration as early as January and February (Moyle 2002a). Pacific lamprey die after spawning; however some adults have been known to survive and spawn again a year later (Moyle 2002a). After eggs hatch in approximately 2–3 weeks, the detritus-eating larvae remain for perhaps 5–7 years in the streams before reaching adulthood and returning to sea (Moyle 2002a). Pacific lamprey are currently present in Putah Creek.

5.1.5 SACRAMENTO-SAN JOAQUIN ROACH

Sacramento-San Joaquin roach (*Lavinia symmetricus* sp. *symmetricus*) is a California Species of Special Concern. It is one of six subspecies of California roach. Sacramento-San Joaquin roach is a small native minnow found throughout the Sacramento-San Joaquin river drainage (with the exception of the Pit River) and tributaries to the San Francisco Bay (Moyle 2002a). Sacramento-San Joaquin roach is abundant in a large number of streams but is now absent from many stream reaches where it once occurred. Sacramento-San Joaquin roach is generally found in small, warm streams. Dense populations are also frequently sighted in isolated pools in intermittent streams. However, within a watershed, roach can be found in a diversity of habitats, from cool headwater streams to warm water areas characterizing many lower stream reaches. It appears to be excluded from many waters by piscivorous (fish-eating) fishes, especially in habitats occupied by introduced piscivorous fishes. Roach is tolerant of relatively high water temperatures (86–95°F) and low oxygen levels, a characteristic that enables it to survive in conditions too extreme for other fishes (Moyle 2002a). Roach reach maturity at 2 or 3 years of age. Spawning occurs between March through early July, when water temperatures exceed 60°F (Moyle 2002a). Sacramento-San Joaquin roach is currently present, but uncommon, in lower Putah Creek and the inter-dam reach. It occurs mainly in the Pleasants Creek tributary (Moyle, pers. comm., 2003).

5.1.6 HARDHEAD

Hardhead (*Mylopharodon conocephalus*) is a California Species of Special Concern. It is a large minnow that resembles pikeminnow. It prefers clear, deep pools and runs with sand-gravel-boulder substrates and slow water velocities. Most of the streams in which it occurs have summer temperatures in excess of 60°F. However, hardhead tends to be absent from streams that have been severely altered by humans and where introduced species, especially sunfish, predominate (Moyle 2002a). Hardhead is widely distributed in low to mid-elevation streams in the main Sacramento-San Joaquin river drainage. Despite its widespread distribution, hardhead populations are increasingly isolated from one another, making them vulnerable to local extinctions (Moyle 2002a). As a result, hardhead is much less abundant than it once was (Moyle 2002a). Hardhead is no longer present in lower Putah Creek (Moyle et al. 1998).

5.1.7 SACRAMENTO PERCH

Sacramento perch (*Archoplites interruptus*) is a Federal Species of Concern and a California Species of Special Concern. It is the only native centrarchid (sunfish) in California. Historically, Sacramento perch was found below 300 feet in elevation throughout the Central Valley, the Pajaro and Salinas rivers, and Clear Lake (Moyle 2002a). Along with the Sacramento pikeminnow (formerly squawfish), it was the dominant piscivorous (fish-eating) fish in waters of the Central Valley. However, Sacramento perch has been extirpated from most of its former range because of the introduction of 11 species of sunfish (Moyle 2002a). Adults do not remain on nests and unguarded eggs are vulnerable to predation. Sacramento perch formerly inhabitated sloughs, slow-moving rivers, and lakes; however, it is now mostly found in reservoirs and farm ponds. Sampling during the 1980s and 1990s indicated that Sacramento perch were no longer present in lower Putah Creek (Moyle et al. 1998). They were re-introduced into the creek in 1997 but failed to become established. However, a small population exists in a pond that drains into Putah Creek (Moyle et al. 2003). Subsequent sampling suggests that Sacramento perch have been unable to maintain a self-sustaining population in lower Putah Creek (Salamunovich, pers. comm., 2003).

5.2 INTRODUCED AND INVASIVE SPECIES

The presence of introduced and invasive fish and invertebrates reflects the history of management objectives and decisions made over time that have altered stream conditions in ways that affect the numbers, types and distribution of fish and aquatic organisms in a stream. An understanding of some of the relationships and needs of these species will help in determining future objectives and decisions for Putah Creek that benefit both fisheries as well as human needs.

5.2.1 INTRODUCED AND INVASIVE FISH

For the purposes of this report, introduced (or exotic), non-native fish are defined as those fish native to other regions of the country or world and introduced intentionally (e.g., for sportfishing, food, mosquito control), or as byproducts of human activity (e.g., release of pet fish, ballast water releases) into California and Putah Creek. Native fish include those that have been in California and Putah Creek for hundreds or thousands of years. Introduced fish are considered invasive if they can drastically reduce, displace, or lead to the extirpation or extinction of native fish species in certain areas or even an entire ecosystem. Determining whether an introduced species is invasive depends both on environmental conditions and whether the species is ecologically similar to the native species (Moyle 2002a). In general, introduced fish often coexist with native fish in relatively undisturbed habitats, while the native species remain dominant (Moyle 2002a). However, introduced species tend to dominate native species in environments highly altered by human activity. If aggressive predatory introduced fish are present (e.g., green sunfish, largemouth bass), they may further threaten native fish populations. Putah Creek is an example of a creek modified by human activities and characterized by a greater diversity and quantity of introduced species than native species (Moyle et al. 2003). However, recent changes to flow releases from PDD are intended to tip the balance in favor of larger native species populations, as is discussed later in this chapter.

An example of the relationship between introduced and native fish species is in the San Joaquin River system where green sunfish are widely distributed in foothill streams. In the undisturbed regions, green sunfish occur only as scattered large adults while native minnows remain abundant. However, where a stream section is dammed or modified in these regions, green sunfish quickly take over and native species become uncommon (Moyle 2002a). Green sunfish are considered invasive in the disturbed areas. However, it important to note that habitat modification could also be responsible for the reduction of native species. Despite poor habitat conditions, native species would likely be present in all disturbed habitats if introduced species were absent (Moyle 2002a).

The reason introduced species generally have negative effects on native species populations stems from the following five types of interactions: competition, predation, habitat interference, disease, and hybridization (Moyle 2002a). *Competition* between an introduced and a native species for limited resources (usually food and space) reduces and sometimes eliminates the native species. *Predation* by introduced fish on native fish is another way that introduced species directly reduce or eliminate native species populations. Larval and juvenile native fishes are particularly vulnerable to predation by introduced species. In lower Putah Creek, largemouth bass are known to feed on native fishes (Moyle et al. 2003). *Habitat interference* occurs when an introduced species' activities change or manipulate the characteristics of the habitat it occupies. These changes can cause native species to leave or suffer reductions in populations (Moyle 2002a). Common carp are known to cause habitat interference by digging up aquatic plants. This increases the amount of suspended matter in the water which, in turn may reduce or eliminate native fish populations that require clear water for sight feeding or breeding. *Diseases*, including parasites, can be brought in by introduced species, especially if they were not quarantined prior to introduction. The diseases may kill or weaken native species that are not immune to them (Moyle 2002a). *Hybridization* (cross-breeding) can occur between two closely related species or subspecies typically producing sterile offspring that cannot reproduce, and result in the reduction or elimination of the native species population.

General declines in native fishes in California and in Putah Creek reflect a changing ecosystem. Measures to protect native fish in Putah Creek could help improve the ecosystem, benefiting both native and valued introduced game species.

5.2.2 INVASIVE AQUATIC INVERTEBRATES

Invasive aquatic invertebrates are introduced invertebrates that can drastically alter the ecology of a body of water such as a lake, stream, estuary, or entire watershed, and as a result, alter, reduce, or eliminate both native and introduced aquatic flora and fauna. Invasive invertebrates can have negative effects on an ecosystem by modifying the food chain and competition, creating habitat interference, and introducing new diseases (see “Introduced and Invasive Fish” subsection above for more discussion on these concepts). Three invasive aquatic invertebrates that may affect or are affecting lower Putah Creek are the Chinese mitten crab (*Eriocheir sinensis*), Asian clam (*Corbicula fluminea*), and New Zealand mud snail (*Potamopyrgus antipodarum*).

CHINESE MITTEN CRAB

The Chinese mitten crab is native to mainland China and coastal areas along the Yellow Sea (Metzler 2003). The crab was first collected in the south San Francisco Bay by commercial shrimp trawlers in 1992 (DFG 1998). By 1998, the mitten crab had spread throughout the Bay and up into the Sacramento River system (Metzler 2003). The Chinese mitten crab reduces the structural integrity of banks and levees, damages fishing nets, clogs fish salvage screens, disrupts ecological structure and function, and is a potential public health concern. The Chinese mitten crab is considered a potential health concern because it is a secondary host to the Oriental lung fluke, which causes tuberculosis-like and influenza-like symptoms in humans who are the final host (Portland State University 2003). However, there is currently no evidence of the presence of Oriental lung fluke in California populations (Moyle, pers. comm., 2003).

Thomas R. Payne and Associates staff captured two Chinese mitten crabs in Putah Creek at Stevensons Bridge on July 8, 1998, and three additional mitten crabs were captured on October 14 and 15, 2002, one each at Los Rios Check Dam, County Road 106A, and Mace Boulevard (Salamunovich, pers. comm., 2003). At present, there is not much concern about the Chinese mitten crab affecting Putah Creek. Mitten crabs are found in low abundance throughout the San Francisco Bay Estuary. Like many new invaders, their populations exploded at introduction but have now tapered off dramatically (Moyle, pers. comm., 2003).

ASIAN CLAM

The Asian clam (*Corbicula fluminea*) is native to temperate and tropical southern Asia, the southeast Asian islands, central and eastern Australia, and Africa (USGS 2000). The first collection of Asian clam in the United States occurred in 1938 along the banks of the Columbia River near Knappton, Washington (USGS 2000). The clam has since spread throughout the United States and is now found in 38 states and the District of Columbia. Ecologically, the Asian clam alters benthic substrate and competes with native species for limited resources. Asian clams are dominant in some riffles along Putah Creek, but their impacts on the creek are presently unknown (Moyle, pers. comm., 2003).

NEW ZEALAND MUD SNAIL

The New Zealand mud snail (*Potamopyrgus antipodarum*) is a small, 0.01- to 0.2-inch-long (0.25 to 5 mm), aquatic mud snail native to lakes and streams of New Zealand. Information on the mud snail and current protocols for minimizing its spread are provided in Appendix G. Removed from the native predators and parasites of its native range, the mud snail has the potential to harm river and stream ecosystems in areas it has been introduced to in North America. It was first reported in England in 1859 and is now widespread there and in several other countries in Europe (Zaranko et al 1997). It is also widespread in Australia. The New Zealand mud snail was first reported in North America in 1987 when it was discovered in the Snake River near Twin Falls, Idaho (Taylor 1987). Since then it has been found in the Columbia and Yellowstone rivers, in the Grand Canyon sections of the Colorado River, and in Lake Ontario. It was first detected in California in the Owens River in 2000. The New Zealand mud snails found in the western U.S. are clones that are genetically similar to specific clones found in Australia and the North Island of New Zealand. The western U.S. populations are dominated by female mud snails that are capable of producing asexually (Dybdahl 2002, Crosier et al. 2004).

The invasive mud snail was first discovered in Putah Creek by Sacramento aquatic biologist Ken Davis on October 30, 2003. By December 2003, the known infested area of Putah Creek was an approximately half-mile-long zone near Fishing Access Site #3 (Appendix G). Based on samples taken, the average density as of November 2003 was about 1,000 mud snails per square yard.

Following detection in lower Putah Creek, the snail was found in the lower Mokelumne River in December 2003 and an 11-mile stretch of the lower Calaveras River-Mormon Slough in January 2004 (Bergendorf 2004). There is no reported documentation as to how the mud snails may have been introduced or spread in California. It has been speculated that the mud snail may have been transported to lower Putah Creek on fishing or boating equipment previously used in infested locations, although other vectors may have accounted for its introduction.

The New Zealand mud snail inhabits both fresh and brackish water and has been found in water up to 26 parts per thousand (ppt) salinity (Winterbourn 1970), with tolerance to higher salinity levels for short duration (i.e., 7 days at 30 ppt) (Hylleberg and Siegismund 1987). However, experimental work indicates that it is active only in water below 17.5 ppt (Winterbourn 1970). The New Zealand mud snail can form dense populations of 500,000 or more individuals per square meter (Richards 2003, Riley 2002). It is as yet uncertain how much of an impact the New Zealand mud snail may have on fish and wildlife populations and ecosystems or on infrastructure such as drinking water conveyance systems. However, documented evidence thus far indicates there may be cause for concern that impacts to ecosystems or infrastructure may occur. Monitoring, education to prevent its spread, and research on whether and how to control the mud snail is on-going.

Preliminary studies indicate the New Zealand mud snail alters primary production (i.e., algae growth) and can result in algal blooms, possibly through nutrient enrichment (Riley 2002). Macroinvertebrates composition and production are also altered in areas where it has been introduced. Kerans (2001) found that 25% to 50% of the macroinvertebrate assemblage consists of the New Zealand mud snail in studies in Yellowstone National Park, with negative correlations found between the snail and mayfly, stonefly, and caddis fly taxa. Hall et al. (in preparation) found that 65% to 92% of the total invertebrate biomass in three Yellowstone Rivers in 2000–2001 studies were New Zealand mud snails. Cada (2003) and Anderson (2002) have found that brown trout and other fish, particularly sculpins, have shown reduced growth in areas infested by the snail, attributed to the reduced densities of macroinvertebrates those fish favor as food. Additionally, the fish have been found to avoid eating the New Zealand mud snails, indicating that the mud snail is not an alternative source of forage. The mud snail appears to be largely indigestible to fish and birds present here because of the mud snail's small size, its shell, and an operculum that it closes tightly, thus protecting its inner body from external digestive fluids (Buttermore 2003). It survives the stomachs of trout for 2.5 to 5 hours (Dwyer 2001) and can survive 20–50 days out of water (Winterbourn 1970). In addition to known and potential impacts to biological systems, the mud snail may become problematic in some drinking water systems or other water conveyance infrastructure. The mud snail has been reported to pass through water pipes and emerge from domestic taps (Ponder 1988) and to block waterpipes (Cotton 1942).

Researchers have found no way thus far to eradicate the mud snail. Fishermen are especially key in preventing the spread of the mud snails to other streams, although it is conceivable that birds and other wildlife could also spread the mud snail. Mud snail posters (Appendix G) were posted along lower Putah Creek by the Putah Creek Council (PCC), LPCCC, and fishing groups within weeks after its discovery to help educate fishermen and the public regarding the mud snail and precautions that should be taken to prevent the spread of this invasive species. Fishing access sites in the vicinity of the infestation were temporarily closed to the public in an effort to contain the infestation and prevent its spread to other areas along Putah Creek and other waterways. However, the signage and closure were insufficient to stop the spread of the snail along Putah Creek. As of June 2004, the New Zealand mud snail has been detected 6 miles downstream of the PDD during ongoing surveys by Ken Davis. Mr. Davis has also found several juveniles in drift material (Marovich, pers. comm., 2003), indicating that to be a primary dispersal mechanism.

5.3 HISTORY OF FISHERIES ON PUTAH CREEK

This subsection provides a historical account of Putah Creek and its fisheries from the period prior to Euro-American settlement to the present. The historical account is divided into sections that are based on periods of different human modifications to the creek and information limited to certain years and time periods. Conditions from four periods are described: (1) prehistoric (prior to mid-1800s), (2) Euro-American settlement (late 1800s through 1950s), (3) Solano Project (1960s to Putah Creek Accord (2000)), and (4) Putah Creek Accord. The Solano Project period is further divided into subsections describing conditions in the interdam reach and lower Putah Creek below the PDD, areas that developed unique characteristics following construction and operation of the Solano Project. The Putah Creek Water Accord is focused on lower Putah Creek below the PDD.

5.3.1 PREHISTORIC CONDITIONS (PRIOR TO MID-1800S)

There is no written documentation from this period. Much of this information is based on the assumptions of fisheries experts and existing scientific evidence, such as current fish distributions, habitat conditions and species assemblages of native fish in relatively pristine areas.

STREAM CONDITIONS

Prior to Euro-American development in the region, Putah Creek flowed out of the mountains spreading out to the Sacramento Valley to the east and southeast, depositing a delta-like sheath of silts, sands, and cobbles moved by major flood events. As this sediment deposition elevated the creek bed, Putah Creek changed its course often, leaving levee-like strips of gravel flanking the channel and finer silt deposits outside of these strips. Subsequent flood events overtopped these natural levees as the creek sought new configurations. This process caused the creek to meander radially across the alluvial fan, depositing sediment as it went (Thomasson et al. 1960).

Prior to Euro-American settlement, lower Putah Creek was flanked by a continuous broad corridor of riparian forest from the Coast Ranges to the Yolo Basin where the creek emptied into an extensive marsh dominated by tules (*Scirpus* spp.) (Kuchler 1977, Katibah 1984). Historical maps and detailed soil surveys indicate that the riparian forest of lower Putah Creek was quite extensive. It covered an estimated area of between 22,000 and 65,000 acres from the site of present-day Winters to the Putah Creek Sinks (Kuchler 1977, Katibah 1984). In most years following winter and spring storms, lower Putah Creek flooded its extensive floodplain riparian forest and the tule marshlands in the Putah Creek Sinks, with portions remaining impassable except by boat for much or all of the wet season (Derby 1849).

The lower Putah Creek watershed was home to the Patwin people, who settled in this area because of the natural abundance of fish and game and its reliable source of water (Russell and Coil 1940). Archaeological studies indicate that the Patwin relied on resident fish for food, such as Sacramento perch, thicktail chub, Sacramento pikeminnow, and tule perch (Kroeber 1932, Schultz and Simons 1973). They also harvested anadromous fish such as Chinook salmon and sturgeon (Schultz 1994).

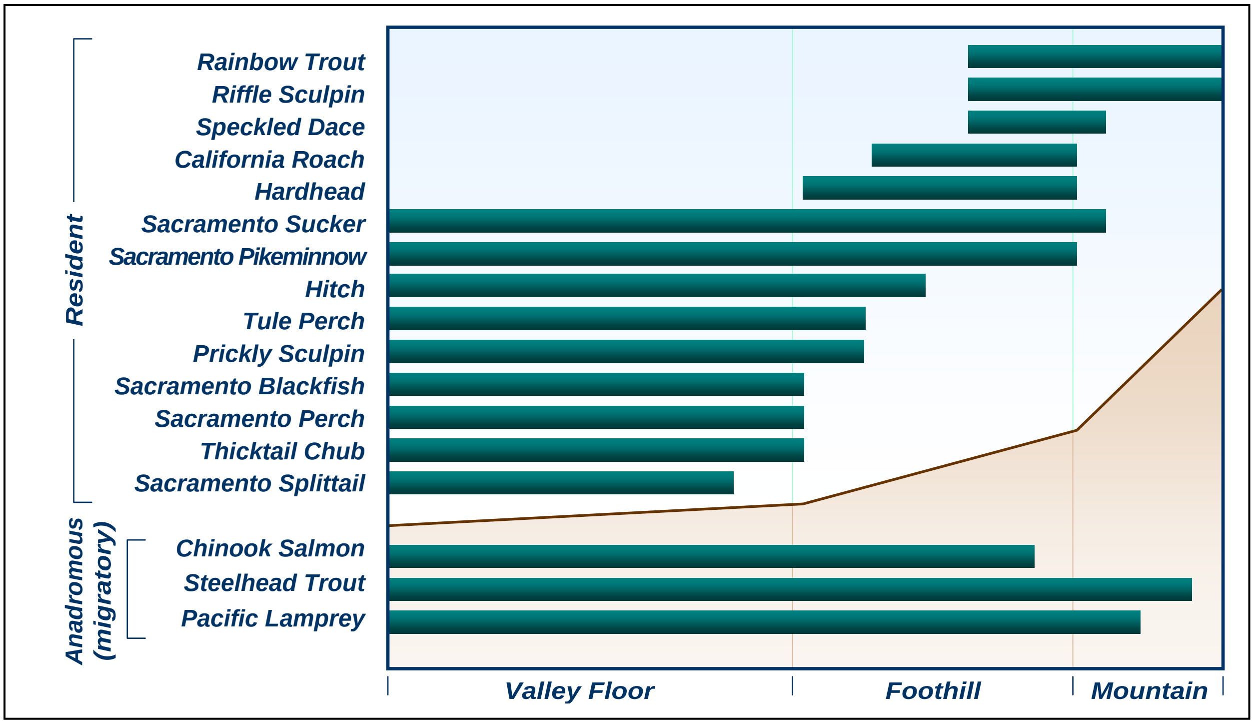
FISHERIES

The historical distribution of common native fishes in Putah Creek reflects the historical distribution of common native fishes in the Central Valley drainage (Moyle et al. 1998). Central Valley streams have headwaters in mountain areas and flow through steep canyons and deep pools in the foothills before flowing into slow-moving rivers or lakes on the valley floor. The habitats found in mountains, foothills, and the valley floor contained distinct assemblages of fish that had wide or narrow zones of overlap, depending on the gradient of the stream and other environmental conditions. In tributaries to the Sacramento River, the overlap among regions with distinct assemblages (often called zones) was fairly broad. Four assemblages can usually be recognized in Central Valley streams: (1) the rainbow trout assemblage, (2) the pikeminnow-hardhead-sucker assemblage, (3) the California roach assemblage, and (4) the deep-bodied fishes assemblage (Moyle 2002a). Each of these assemblages and their likely historical distribution in Putah Creek are described below.

Historically, Putah Creek supported populations of all native resident fishes of the Sacramento Valley in a series of assemblages that change with elevation (Exhibit 5-1) (Moyle et al. 1998). Anadromous fishes, including steelhead, fall-run chinook salmon, and Pacific lamprey, were also present in low numbers (Moyle et al. 1998).

Rainbow Trout Assemblage

The high elevation reaches of Putah Creek near Cobb Mountain supported the rainbow trout assemblage. This zone is characterized by clear streams at high elevations where stream gradients are high (usually a total drop of at least 15 feet for every mile of stream). The water is cold, seldom exceeding 21°C (69.8°F), and is saturated with oxygen. Stream bottoms consist mostly of cobbles, boulders, and bedrock. The banks are well shaded and frequently undercut; logs and root wads often extend into the water, creating pools and other cover. There are few submerged or emergent aquatic plants, except where streams flow through boggy alpine meadows. In the high elevation reaches, the dominant native fish was rainbow trout, but sculpin (usually riffle sculpin), Sacramento sucker, and speckled dace were often part of this assemblage. California roach also may have been found in these reaches (Moyle 2002a). California roach are found in upper Pope Creek, a tributary of Lake Berryessa. (Moyle, pers. comm., 2003).



Source: Moyle et al. 1998

Historic Distribution of Common Native Fishes in the Central Valley Drainage of California, Including Putah Creek

EXHIBIT 5-1

Pikeminnow-Hardhead-Sucker Assemblage

The foothill area of Putah Creek supported the pikeminnow-hardhead-sucker assemblage, which occurred at elevations between about 270 and 1,700 feet (Moyle 2002a). This area would most likely have been the stretch of Putah Creek southeast of Cobb Mountain to the location of the present-day PDD. The pikeminnow-hardhead-sucker fish assemblage zone is characterized by streams that have average summer flows greater than 10 cfs; deep, rocky pools; and wide, shallow riffles. Water quality is usually very good (high clarity, low conductivity, high dissolved oxygen, and summer temperatures between 19 and 22°C [66.2 to 71.6°F]), with complex habitat created by stream meanders and riparian vegetation. However, some streams may become intermittent in summer, or have such reduced flows that fish are confined to pools. Summer water temperatures in such streams may exceed 25°C (77°F) and may track air temperatures closely.

Sacramento pikeminnow (formerly squawfish) and Sacramento sucker were usually the most abundant fishes of this assemblage. Other fishes that were part of this assemblage include hardhead, tule perch, speckled dace, California roach, riffle sculpin, and rainbow trout. Anadromous fishes (mainly chinook salmon, steelhead rainbow trout, and Pacific lamprey) had spawning grounds in the same zone (Moyle 2002a). The Berryessa Valley, which is now filled by Lake Berryessa, and its tributaries supported spawning grounds for chinook salmon and

Pacific lamprey that would migrate upstream during high winter flows (Moyle 2001b). Steelhead probably continued up through the Berryessa Valley and spawned in Putah and Pope Creeks (Crain, pers. comm., 2003).

California Roach Assemblage

The California roach assemblage occurred in small, warm tributaries such as Pleasants Creek, to larger streams that flowed through open foothill woodlands of oak and foothill pine (Moyle 2002a; Moyle, pers. comm., 2003). Streams that supported the California roach assemblage are located in the foothills in much of the same region that contained the pikeminnow-hardhead-sucker assemblage. The streams were usually intermittent during summer, so fish were often confined to stagnant pools that may have exceeded 30°C (86°F) during the day. In winter and spring the streams were swift and subject to flooding. The primary permanent resident in this zone was the California roach. Because of its small size and tolerance of low oxygen levels and high temperatures, roach survives where most other fish cannot. During winter and spring, Sacramento sucker, pikeminnow, and other native minnows may have used the streams for spawning and rearing (Moyle 2002a).

Deep-Bodied Fish Assemblage

A deep-bodied fish assemblage occupied the warm waterways of the valley floor, including slow-moving channels, oxbow and floodplain lakes, swamps, and sloughs (Moyle 2002a). This zone would have occurred in the floodplain of Putah Creek that begins where the PDD is now located, and continued east through the Yolo Basin to the Sacramento River.

Fishes of the deep-bodied fish assemblage were found in a variety of habitat types ranging from stagnant backwaters and shallow tule beds to deep pools and long stretches of slow-moving river water (Moyle 2002a). Sacramento perch, thicktail chub (*Gila crassicauda*), tule perch and juvenile fishes predominated in the weedy backwaters while specialized adult cyprinids such as hitch (*Lavinia exilicauda*), Sacramento blackfish, and Sacramento splittail occupied large stretches of open water. There was also an abundance of large pikeminnows and suckers in this zone, which migrated upstream to spawn in tributaries in the spring. Anadromous salmon, steelhead and lampreys passed through this zone on their way upstream to spawn (Moyle 2002a).

5.3.2 EURO-AMERICAN SETTLEMENT PERIOD CONDITIONS (LATE 1800S THROUGH 1950S)

STREAM CONDITIONS

Historic hydrology and geomorphology of Putah Creek are discussed in section 4.3.1, "Hydrology Prior to the Solano Project." Riparian vegetation was continually removed along Putah Creek to accommodate the expansion of agriculture in the area (Shapovalov 1946), but the greater effect on fish was likely due to vegetation removal in the channel itself that was performed by the USACE. The narrowing of the riparian corridor and removal of overhead shade cover allowed for greater warming of the water. The flood control modifications also likely reduced flow velocities and increased the ratio of still to flowing water by widening the channel and eliminating floodplains within the incised channel (Marovich, pers. comm., 2003). The lower flow velocities and higher ratio of still to flowing water would have increased the residence time of water in the channel, resulting in higher average water temperatures that also favored exotic fish (Marovich, pers. comm., 2003). These alterations probably increased habitat for introduced warmwater species such as common carp, bluegill, and smallmouth bass, because they thrive in environments that have been modified/disturbed (i.e., by vegetation removal, channel modification), whereas native species generally do not do well in disturbed environments.

Leo Shapovalov, a DFG biologist, described summer baseflow conditions in upper and lower Putah Creek in his 1940 report (Shapovalov 1940). Shapovalov's descriptions, considered together with a review of historical topographic maps and interviews of historical witnesses, documented that there was perennial flow throughout the following reaches of Putah Creek and perhaps additional reaches: (a) upper Putah Creek from the confluence with Capell Creek to Devil's Gate (approximately 7 miles long—this stretch of Putah Creek is now at the bottom of Lake Berryessa), (b) between the present day sites of Monticello Dam and the Pleasants Valley Road Bridge over present day Lake Solano (approximately 6 miles long), and (c) lower Putah Creek near Stevensons Bridge. Shapovalov's data documented that in most years there were permanent pools and surface flows over short reaches where emergent groundwater entered the creek in the vicinity of Stevensons Bridge (Shapovalov 1940). Records from the DWR Putah Creek Cone Investigation (1955) and the USGS Water Supply Paper 1464 (Thomasson et al. 1960) also support Shapovolov's findings (Jones & Stokes Associates [JSA] 1992). During the July–October period of 1949–1954, DWR and USGS recorded stream flows at Stevensons Bridge when no flow occurred at both Winters and Davis (DWR 1955; Thomasson et al. 1960).

In 1959, Reclamation completed the Solano Project consisting of two water storage facilities and a water delivery system: Monticello Dam, PDD, and Putah South Canal. Water deliveries began on May 15, 1959. The project resulted in the highly regulated streamflow regime that currently exists in lower Putah Creek. Details of the Solano Project and the effects it had on the hydrology of Putah Creek are provided in Chapter 4, "Geomorphology, Hydrology, and Water Quality."

FISHERIES

The first formal records describing fish species in lower Putah Creek were developed by ichthyologists from Stanford University and the California Academy of Sciences and published in 1912. Researchers collected a diverse assemblage of native fish, including Sacramento splittail, hardhead, and thicktail chub. These fish and other Putah Creek native fish were large (8 inches as adults), long-lived species that would have required permanent water to maintain these populations of fish during the period that they were collected (Trihey & Associates 1996).

Many non-native fishes were introduced or spread into the creek starting in the late 19th century. Species such as white catfish, bluegill, smallmouth bass, and common carp eventually came to dominate the fisheries in the creek. Smallmouth bass were in the foothill reach along with carp (escapees from ponds in the Berryessa Valley) and probably catfish as well (Moyle et al. 1998; Moyle, pers. comm., 2003).

5.3.3 SOLANO PROJECT PERIOD CONDITIONS (1960S TO PRESENT)

The Solano Project was completed in 1959. It enabled provision of important water resources for thousands of farmers, rural homes, and urban residences and businesses throughout Solano County, as well as recreational opportunities users throughout the region. A description of the Solano Project and its impor tance to water users can be found in "The Solano Water Story – A History of the Solano Irrigation District and the Solano Project (Rubin, Kahn and Kahn, 1988). However, it also greatly modified Putah Creek and its fisheries. Putah Creek waters were impounded by the Monticello Dam, flooding the Berryessa Valley and creating Lake Berryessa. PDD, constructed 6 miles downstream from Monticello Dam, impounded flows in the "interdam reach," creating Lake Solano. This subsection provides an account of the changes that occurred to Putah Creek and its fisheries following completion of the Solano Project, including changes to fisheries taking place following implementation of the Putah Creek Water Accord.

PHYSICAL CHANGES TO LOWER PUTAH CREEK

Altered flow regimes have profound effects on the ecology of streams (Marchetti and Moyle 2001). These include changes in physical characteristics such as channel structure, sediment transport, and thermal regime, and changes in biological characteristics such as species diversity, trophic structure, and community composition. Usually, the most obvious ecological effect of stream regulation is a collapse or change in fish populations (Marchetti and Moyle 2001).

The Solano Project resulted in major changes to hydrological and geomorphological patterns in the creek, discussed in more detail in Chapter 4, "Geomorphology, Hydrology, and Water Quality." It also resulted in three separate fish communities in Putah Creek: the upper watershed reach, consisting of Lake Berryessa, the upper creek, and tributaries above Monticello Dam; the interdam reach, between Monticello Dam and PDD; and lower Putah Creek below the PDD. The fish in the upper watershed and interdam reaches, amounting to approximately 90% of the total Putah Creek watershed area became isolated from each other and separated from the fish below the PDD, as PDD is impassable to migrating fish). Lake Berryessa covers nearly 14 miles of the original Putah Creek channel (Moyle et al. 1998). Putah Creek now supports a cold-water trout fishery extending downstream from Monticello Dam to 1 to 2 miles below the PDD, with cool-water habitat down to about Pedrick Road (Road 98) and warm-water habitat from Pedrick Road to the Yolo Bypass.

INTERDAM REACH

The interdam reach is a 6-mile-long section of lower Putah Creek beginning at Monticello Dam and ending at the PDD. The PDD created the Lake Solano, an approximately 1.5-mile-long reservoir. Water from Putah Creek is impounded at PDD. Between Monticello Dam and Lake Solano, several fishing access sites were established following creation of a cold-water trout fishery, discussed below. The access sites are owned by DFG and managed by the Yolo County Parks Department. (Chapter 3, "Land Ownership, Land Use, & Resource Management Programs," includes discussions of recreational areas and opportunities.)

Stream Conditions

With construction and operation of the Monticello Dam, the cold water released from the bottom of Lake Berryessa converted the interdam reach from a warm water reach to a cold-water reach (USFWS 1993). Sediment transport patterns to and through this reach were greatly altered as sediment from the upper watershed was impounded above Monticello Dam and sediment from interdam tributaries including Thompson Creek, Pleasants Creek, and Cold Creek began filling the newly created Lake Solano. A portion of the capacity of Lake Solano was quickly lost due to sediment accumulation soon after the lake was formed. In recent years, Lake Solano has reached equilibrium where sediment inflows are equal to sediment outflows during high-water events with little effect on capacity (Northwest Hydraulics, 1998). Year-round flows from Monticello Dam and a lack of vegetation clearing may have led to what is now considered some of the best riparian habitat in the region (Kemper 1996).

Fisheries

The interdam reach is typical of stream reaches below many dams. Prior to construction of the Monticello Dam, this portion of the creek was a perennial stream that supported populations of native fishes and introduced game fish such as smallmouth bass and channel catfish. Following construction of the dam, however, the reach became a year-round cold-water trout stream because cold water is released from the bottom of Lake Berryessa (USACE 1993, Shapovalov 1947).

The interdam reach is managed by DFG during spring and summer as a "put and take" fishery for hatchery-reared rainbow trout. The winter fishery is primarily for wild, naturally spawned rainbow trout and hatchery-origin brown trout. On an annual basis, DFG indicated that this reach has one of the highest rates of angler use per mile of any similar-sized stream in the state (USFWS 1993) (Exhibit 5-2). Currently, the creek supports a relatively healthy and productive cold-water fishery, including a population of naturally reproducing rainbow trout (USFWS 1993).

To help maintain the quality of the trout fishery, the interdam reach has twice been subjected to chemical treatment with rotenone, in 1955 and 1971, prior to stocking with rainbow trout (USFWS 1993). Treatment was focused on carp and native fishes on the false assumption that

Local fly fishing enthusiast Bernie Weston and rainbow trout caught in late 2003 in the interdam reach. The Putah Creek interdam reach, between Monticello Dam and the Putah Diversion Dam at Lake Solano, is widely known for trout fishing.

A 30-inch adult chinook salmon that was captured in the boulder riffle/pocket water area 100 feet below Putah Diversion Dam in October 2003.

Source: Steve Spiller, Thomas R. Payne and Associates, 2003

Trout Fishing and Salmon Returning

EXHIBIT 5-2

EDAW

they compete with trout. The rotenone treatment probably had little to do with the success of the fishery; the fishes that were poisoned do not typically thrive in cold water anyway (Moyle, pers. comm., 2003). Cold flows and heavy planting was likely all that was needed to promote a trout fishery (Moyle, pers. comm., 2003).

Despite past efforts with chemical treatments, trout still share the interdam reach with native and non-native non-game fish today. Fish inhabiting the interdam reach can be divided into three categories: introduced game fish, introduced non-game fish, and resident native fish. Introduced game fish stocked by the DFG include rainbow trout, brown trout, and brook trout. Before 1973, DFG stocked fingerling rainbow trout that presumably developed into the naturally reproducing population that currently exists (USFWS 1993). Catchable rainbow trout were planted in 1962. Brook trout were planted in 1966 (Salamunovich, pers. comm., 2003). Catchable-sized rainbow trout have been stocked on a yearly basis since 1973. DFG records show that between 1961 and 1985, 81% of the stocking were rainbow trout, 18% were brown trout, and 1% were brook trout. However, there are no longer brook trout in lower Putah Creek (Moyle, pers. comm., 2003).

The native fish that still persist in the interdam reach today include hitch, California roach (Sacramento-San Joaquin subspecies), Sacramento pikeminnow, Sacramento sucker, three-spine stickleback, and riffle sculpin. In October 2003, New Zealand mud snail was discovered in this reach, near Fishing Access Site #3 (see Section 5.2, "Introduced and Invasive Species") raising concerns about potential impacts to trout and other fish species.

LOWER PUTAH CREEK DOWNSTREAM OF PUTAH DIVERSION DAM

Stream and fisheries conditions in lower Putah Creek downstream of the PDD have been affected and shaped by several factors, including aforementioned flood control grading and vegetation removal, gravel mining, blocking off of the North Fork channel, construction of the South Fork, construction of the Solano Project, operation of the PDD, and, in May 2000, settlement and implementation of the historic Putah Creek Water Accord. This subsection discusses the stream and fisheries conditions following operation of the Solano Project and following implementation of the Accord.

Stream Conditions Prior to Water Accord (1960s to 2000)

Construction and operation of the Solano Project had major effects on flows and sediment conditions downstream of the PDD. These are discussed in detail in Chapter 4, "Geomorphology, Hydrology, and Water Quality," and in the subsection, "Spawning Habitat Conditions in Lower Putah Creek," below. In general, the Solano Project substantially decreased total annual discharges through lower Putah Creek compared with pre-project conditions. Prior to construction and operation of the Solano Project, the estimated average annual flow was about 375,000 acre-feet, with most of the discharge occurring during the wet season (December through April) (Jones & Stokes 1992). Following operation of the project, the minimum normal and dry year annual releases required (by a 1970 SWRCB decision) were about 22,000 acre-feet and 19,000 acre-feet, or 6 percent and 5 percent of the estimated pre-project discharges, respectively. However, actual flows had been much higher due to reservoir spills. Actual releases averaged 82,600 acre-feet (23% of pre-Solano Project conditions) between 1971 and 1981 (Jones & Stokes 1992). The Project also modified summer hydrological conditions, extending streamflow throughout summer, such that median flows in August through October were higher than during pre-project conditions, and flows were generally present from the PDD to the Yolo Bypass in most years. (See Table 4-2 in Chapter 4, "Geomorphology, Hydrology, and Water Quality.") However, significant periods of reduced flows in the lowest reaches of Putah Creek occurred at various times since the Solano Project became operational. The 1987–1992 drought years were the driest 6-year period on record for the Putah Creek drainage. At the same time, surface water diversions and increased groundwater pumping were further reducing Putah Creek flows due to a shortage of surface water supplies (Sanford, pers. comm., 2003). The reduced releases during drought years, coupled with reduced recharge from the adjacent groundwater table, resulted in the complete dewatering of long stretches of the creek, major fish die-offs, and raised concern for fish habitat and other beneficial functions of Putah Creek.

The impoundment of gravel upstream of the dams has resulted in a lack of gravel substrate in Putah Creek downstream of the PDD. In addition to the reduction in sediment movement downstream following completion of the Solano Project, gravel mining occurred along Putah Creek during the 1960s and 1970s from the PDD to a point 3 miles downstream, and in the vicinity of Pedrick Road (USFWS 1993). It also occurred sporadically in between those two areas and to a lesser extent elsewhere (Marovich, pers. comm., 2003). Channel surveys in 1972 indicated that mining had left a wide, relatively flat channel with a few artificial berms and levees (JSA 1992).

Vegetation clearing activities in the creek channel by state and federal agencies continued through the 1960s and early 1970s. After 1975, when vegetation clearing policies were changed (USFWS 1993), the creek bed stabilized, riparian woodland cover increased, and a seemingly more natural stream channel was created (Moyle 1991).

Lower Putah Creek below the Diversion Dam exhibits a very different character than the interdam reach does. The primary difference is warmer summer water temperatures resulting from low summer flows, deepening of the channel from gravel mining and flood control work, beaver activity, and narrowing of the riparian corridor. In summer, lower Putah Creek is characterized by flowing stretches and more permanent deep pools. Flows to these reaches come from the PDD and are enhanced to a limited extent by flows from the Willow Canal, and by waste water effluent, specifically from the aquaculture facility and sewage treatment plant on the UC Davis campus. Rising groundwater, when present, can also contribute up to 20 cfs depending on the season and hydrologic year (Sanford, pers. comm., 2003). During winter and spring, flows can increase substantially following rainfall events. In years of heavy rainfall, peak flows may result from uncontrolled spills from Monticello Dam when Lake Berryessa is at capacity or by inflow from tributaries upstream or downstream of PDD. Tributaries downstream of Monticello Dam include Thompson Creek, Cold Creek, Pleasants Creek, and

Dry Creek, all of which are largely unregulated and can contribute high flows to lower Putah Creek.

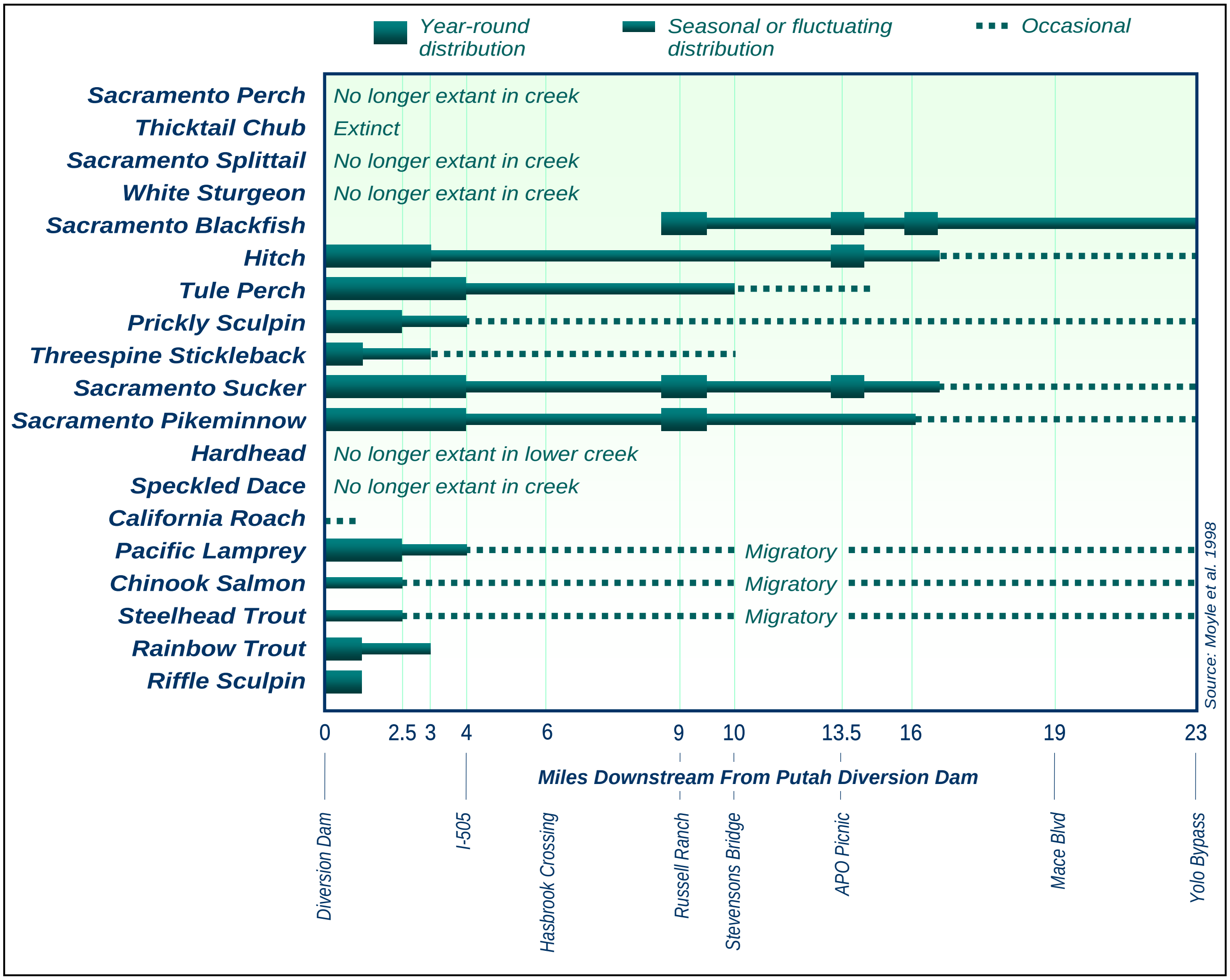
Fisheries Prior to Water Accord (1960s to 2000)

About 40 species of fish have been reported from lower Putah Creek below the PDD, including 17 permanent residents (LPCCC 2003, Moyle 1991, Marchetti and Moyle 2001). The fish species could be divided into four categories: anadromous fish, resident native fish, introduced resident game fish, and introduced resident non-game fish. Sightings of anadromous fish, including spawning activity by small numbers of chinook salmon, occurred when there were adequate late fall and winter flows in Putah Creek, the Yolo Bypass, and the Sacramento River. In addition, based on surveys conducted since the early 1990s, Pacific lamprey larvae are caught in most years (LPCCC 2003).

Native resident fishes in the creek included mainly Sacramento blackfish, hitch, prickly sculpin, riffle sculpin, Sacramento pikeminnow, Sacramento sucker, three-spine stickleback, and tule perch (USFWS 1993). Introduced game species in the creek provided many opportunities for angling. These included species such as brown trout, largemouth bass, smallmouth bass, bluegill, green sunfish, warmouth, white and black crappie, white catfish, channel catfish, black bullhead, and common carp (USFWS 1993, Moyle 1991). Spotted bass were recently discovered in lower Putah Creek although they have long been known to occur in Lake Berryessa (Moyle, pers. comm., 2004).

Two introduced species used as biological agents to control insects by the state, mosquito fish and inland silverside, were extremely abundant in the lower creek. These species served as important prey for piscivorous fish and birds. Goldfish and bigscale log perch populations were likely the result of accidental releases, and other introduced species such as fathead minnow golden shiner and red shiner may have become established as a consequence of discarded fishing bait. Mosquitofish were deliberately introduced into Putah Creek (one of the first sites where they were introduced for mosquito control in California). Silversides came from the Willow Canal (Moyle, pers. comm., 2003). However, any of these species may also have colonized the lower creek from downstream areas during high-flow periods (USFWS 1993).

Exhibit 5-3 depicts the typical distribution of native fish in lower Putah Creek between 1980 and 1995. Of the 19 fish listed, five were listed as no longer present in the creek and one is extinct. Native fish that are no longer present in the creek include thicktail chub, Sacramento splittail, white sturgeon, hardhead, and speckled dace. Hardhead and speckled dace are probably present in the basin above Lake Berryessa (Salamunovich, pers. comm., 2003). Sacramento perch were absent and were re-introduced into the creek in 1997; however, they are not established (Moyle et al. 2003). Most native fish remaining in the creek were prominent mainly in the first 4 miles downstream of the PDD. Four others, including hitch, tule perch, Sacramento sucker, and Sacramento pikeminnow were found to occur seasonally to year-round extending downstream from the Diversion Dam to Stevensons Bridge (tule perch) and downstream of Old Davis Road (hitch, sucker, and pikeminnow). Sacramento blackfish, unique in distribution among the native fish, tended to occur seasonally to year-round in the

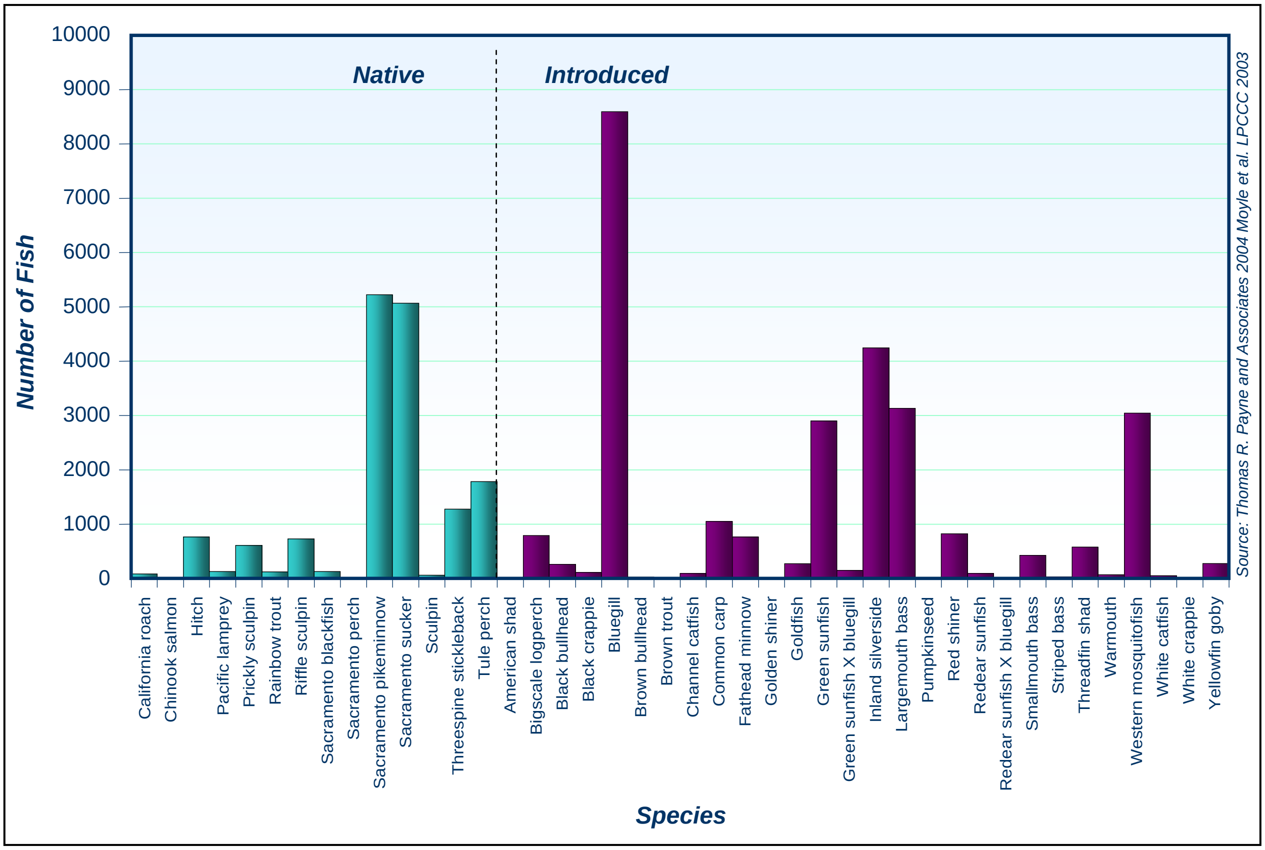


Typical Distribution Pattern of Native Fishes in Lower Putah Creek, 1980–1995

EXHIBIT 5-3

downstream half of lower Putah Creek. Sacramento blackfish is an unusual native fish species because it occurs in warm, usually turbid waters of the Central Valley floor in habitats that are otherwise dominated by non-native species (Moyle 2002a).

Based on lower Putah Creek fish sampling data, 39 species of fish and two hybrid types were collected in lower Putah Creek between 1991 and 2002 (Moyle et al. 2003). Thirteen of these species are native to the creek and 26 species are introduced (Exhibit 5-4). The hybrid types were crosses between introduced species, including bluegill and redear and green sunfish. The most common native fish in the creek included Sacramento pikeminnow, Sacramento sucker, and tule perch, all resident fish. The ten remaining native fish in the creek included eight more resident fish and two anadromous fish. The resident fish included California roach, hitch, prickly sculpin, riffle sculpin, rainbow trout, Sacramento blackfish, Sacramento



Cumulative Fish Catches for Lower Putah Creek, 1991–2000 EXHIBIT 5-4

perch, and three-spine stickleback. The two anadromous fish included Pacific lamprey and fall-run chinook salmon. Common introduced species in the creek included bluegill, green sunfish, largemouth bass, western mosquitofish, and inland silverside.In May 1999, Pacific lamprey were first observed spawning by John Hasbrook, a landowner east of Winters (Putah Creek News 1999). Tim Salamunovich of Thomas R. Payne and Associates observed spawning lampreys upstream of Winters near Dry Creek about one week later (Salamunovich, pers. comm., 1999). The crossing was recently (2003) reconfigured into a "W-weir" by the stream restoration firm Streamwise to maximize spawning habitat for anadromous fishes (Exhibit 5-5) (Marovich 2003).

Regarding the lamprey observations, Tim Salamunovich reported the following: "Canoed Putah Creek from Solano Dam downstream to Old Davis Road on Wednesday and Thursday. Thought you might be interested to known that we saw three Pacific lampreys, 14–18 inches in length, about 1,000 feet downstream of Dry Creek confluence. Two were holding in a shallow riffle area and a third was upstream about 30 feet at the pool tail out constructing a nest under a small limb in the stream. The lamprey was actually picking up the large gravels (4–5 inches)

Before: Pacific lamprey were first observed in 1999 spawning at this low water crossing on the Hasbrook property in Reach 4. In response to this benefit, other landowners have recently expressed interest in installing or augmenting gravels on their properties to provide spawning habitat for anadromous fish.

After: To enhance fish habitat and structural stability, the Hasbrook crossing was re-configured to a W-weir and additional rock was added in September 2003 by the restoration firm, Streamwise. The rocks rise toward the bank to protect against erosion and are submerged at the upstream end to provide for fish passage even at low flows. The project was funded by the USFWS Partners for Wildlife program in cooperation with the LPCCC.

Source: Marovich 2003, EDAW 2003

Anadromous Fish Spawning Habitat Restoration Site

EXHIBIT 5-5

and moving them out of the nest to form the circular "pot." Very interesting to watch. It was amazing how industrious the lamprey was and quite "single-minded" as it continued it nest building despite our presence and movement near its nest." (Salamunovich, pers. comm.,1999). The locations of the two lamprey spawning sites are provided in Subsection 5.4.4, "Potential Spawning Habitat."

During the 1990s, fall-run chinook salmon were only occasionally present in the creek in very low numbers. Chinook salmon were observed spawning near Stevensons Bridge in December 1997 and January 1998 (Sherwin 1998). Chinook salmon juveniles were sampled in spring 1995 at Dry Creek, Old Davis Road, and Mace Boulevard; in spring 1997 at Pedrick Road; and in March 1998 at Mace Boulevard (DWR 2003). However, in late fall 2003, one of the largest runs of chinook salmon occurred in the creek since the completion of the Solano project and is discussed in Subsection, "Post Accord Conditions," below. An estimated 100 fish produced over 30 redds. Steelhead were sometimes reported to occur downstream of the PDD but the reports are unconfirmed (Moyle and Crain 2003).

Fish Distribution in Response to Wet and Dry Year Flow Releases

Species' ranges are a component that can be used to directly evaluate the health of a stream (Moyle et al. 2003). Optimally, a stream is healthiest when all the species in the stream are native to the stream and there are no introduced species, especially no invasive species. In lower Putah Creek, fish sampling by Peter Moyle and Thomas R. Payne and Associates from 1991 to 2002 indicates that the number of introduced species exceeded the number of native species at all but one sampling site. However, the number of individual native fish exceeded the number of introduced fish at many sites, depending on the year (Moyle et al. 2003). Overall, introduced species outnumber native species 26 to 13 species (excluding hybrids) in lower Putah Creek. Once established in a system, introduced fish are difficult to extirpate. However, modifying stream characteristics such as flow volume, channel form, substrate type, riparian corridor width and structure, and overhead vegetation can affect water temperature, water velocity, and other attributes that increase spawning and rearing habitat for most native species while reducing habitat conditions for introduced species. Thus, while introduced species may not be eliminated, conditions can be modified to tip the balance in favor of native species, leading to an increase in their population sizes and distribution.

In their study on the effects of flow regime on fish assemblages in lower Putah Creek, Moyle and Marchetti found that when stream flow increased, the numbers of native fish increased while the numbers of non-native fish decreased (Marchetti and Moyle 2001). Their results indicated that variability in hydrology between years and seasons had a large effect on the fish assemblages in lower Putah Creek. Conditions for native species improved during years with large peak flows in winter and sustained flows in summer, while conditions for non-native species improved during years without high peak flows and with intermittent summer flows (Marchetti and Moyle 2001). High winter and spring flows created conditions that favored reproduction by the native fishes, which typically spawn from mid-February through mid-April. Increased summer flows, such as those resulting from the Accord, also favor native fishes by providing longer reaches of cool flowing water where juveniles could find suitable conditions for rearing. These flows simultaneously reduce the favorability of the habitats for spawning and rearing of non-native fishes. Most of the non-native fishes are summer spawners and favor warm (>75.2°F), quiet water (Marchetti and Moyle 2001).

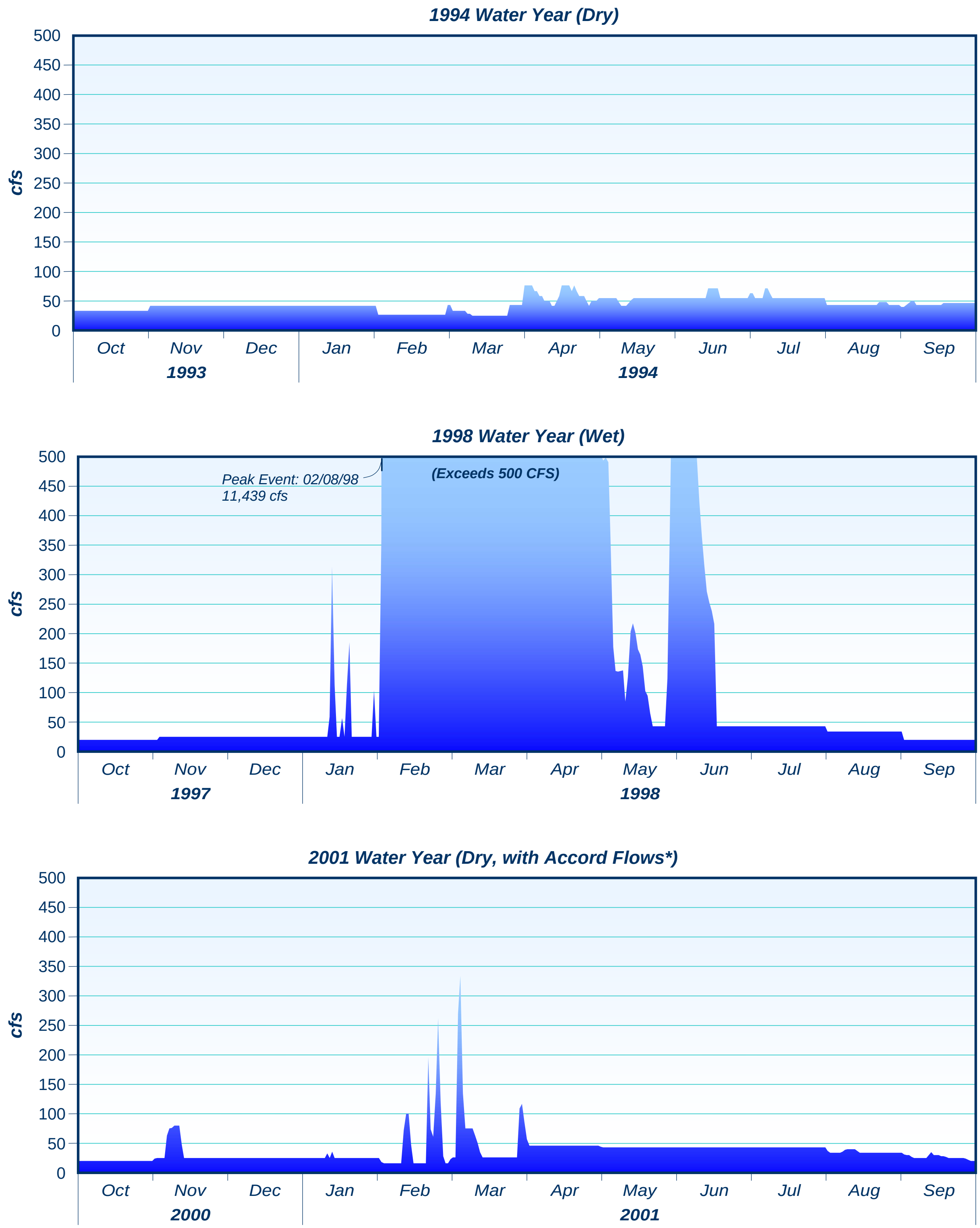
The distribution of native and non-native fish in lower Putah Creek following wet and dry water years reflects Marchetti and Moyle's findings. In studies conducted by Dr. Peter Moyle on Putah Creek, a water year is defined by two parameters: the number of days with PDD releases greater than 50 cfs, and the number of days over 1,000 cfs. A release of 50 cfs is approximately double the quantity of water needed to maintain a continuous flow throughout the creek. An average daily release of 1,000 cfs is equivalent to a flood event. These parameters are used to designate three water year categories: dry, moderate, and wet. Table 5-1, below, provides the criteria for determining water years. Flow releases from the PDD during representative water years are shown in Exhibit 5-6.

Table 5-1
Criteria for Determining Water Year[1] Types in Lower Putah Creek

Water Year Type	PDD Average Daily Releases Exceeding 50 cfs (number of days)	PDD Average Daily Releases Exceeding 1,000 cfs (number of days)
Dry	Less than 30/year	--
Moderate	At least 30/year	Less than 30/year
Wet	At least 50/year	At least 30/year

[1] 1994 Water Year begins October 1, 1993, and ends September 30, 1994.
Source: Moyle et al. 2003

Exhibit 5-7 shows that the percentage of native fish in lower Putah Creek increased in response to the wet year flows of 1996–1999. The characterization of wet, moderate, and dry years is Exhibits 5-8 and 5-9 show the distribution and proportion of native and non-native fish sampled in lower Putah Creek in 1995 and 1999, respectively. Exhibit 5-10 shows the locations of fish sampling sites from 1991 to present. The fish distribution exhibits highlight the proportion of the common native (i.e., Sacramento pikeminnow, Sacramento sucker, and tule perch) and non-native (i.e., bluegill, green sunfish, green sunfish-bluegill hybrid, and largemouth bass) species that occur most frequently. The years shown are representative of fish population patterns following dry (e.g., 1994) and wet (e.g., 1998) years. In general, native fish species were more numerous in the reaches below the PDD and introduced species were more numerous in the lower reaches. However, in a year (e.g., 1995) following a number of dry years, native fishes were mostly concentrated near the Diversion Dam and the number of native fishes declined sharply a short distance downstream from the Dam. In contrast, introduced non-native fish were abundant and dominated all reaches except immediately downstream of the Diversion Dam. Bluegill was the most abundant fish overall in lower Putah Creek in 1995. Both native and non-native fish were present in generally small numbers in all locations in the creek where they did not dominate.

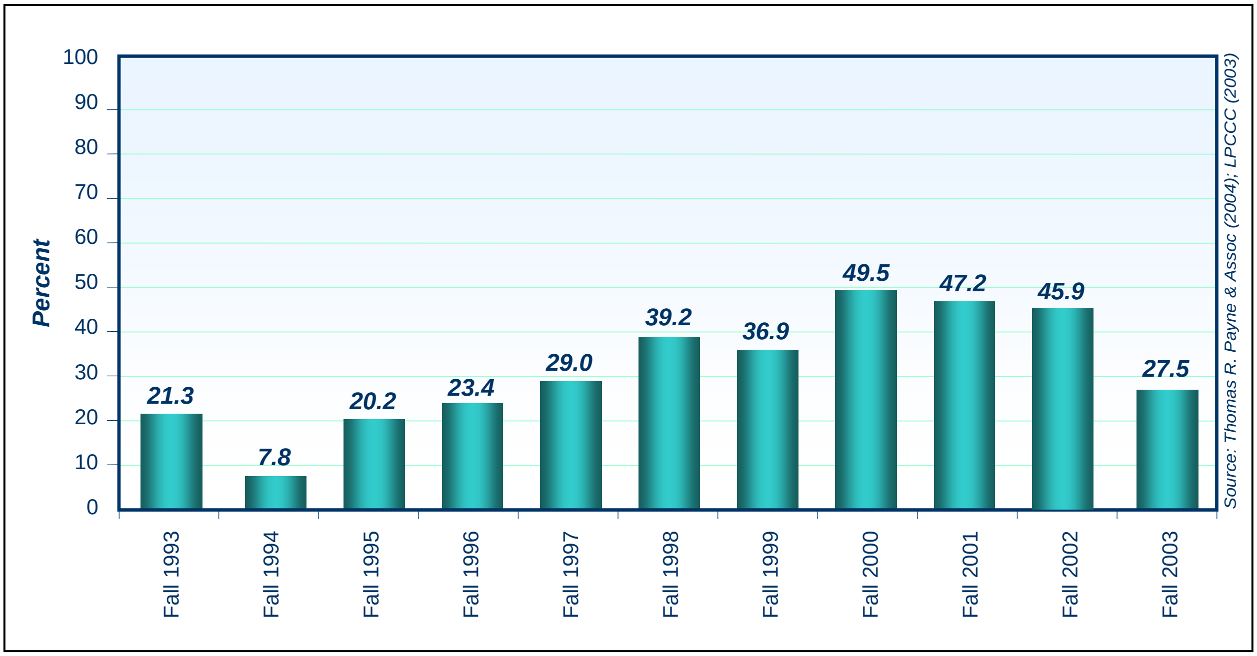


* Accord flow requirements were in effect; however, peak flows in 2000-2001 were natural occurrences unrelated to Accord pulse flow requirements

Source: Solano Irrigation District 2004

Flow Releases from Putah Diversion Dam During Representative Water Years

EXHIBIT 5-6

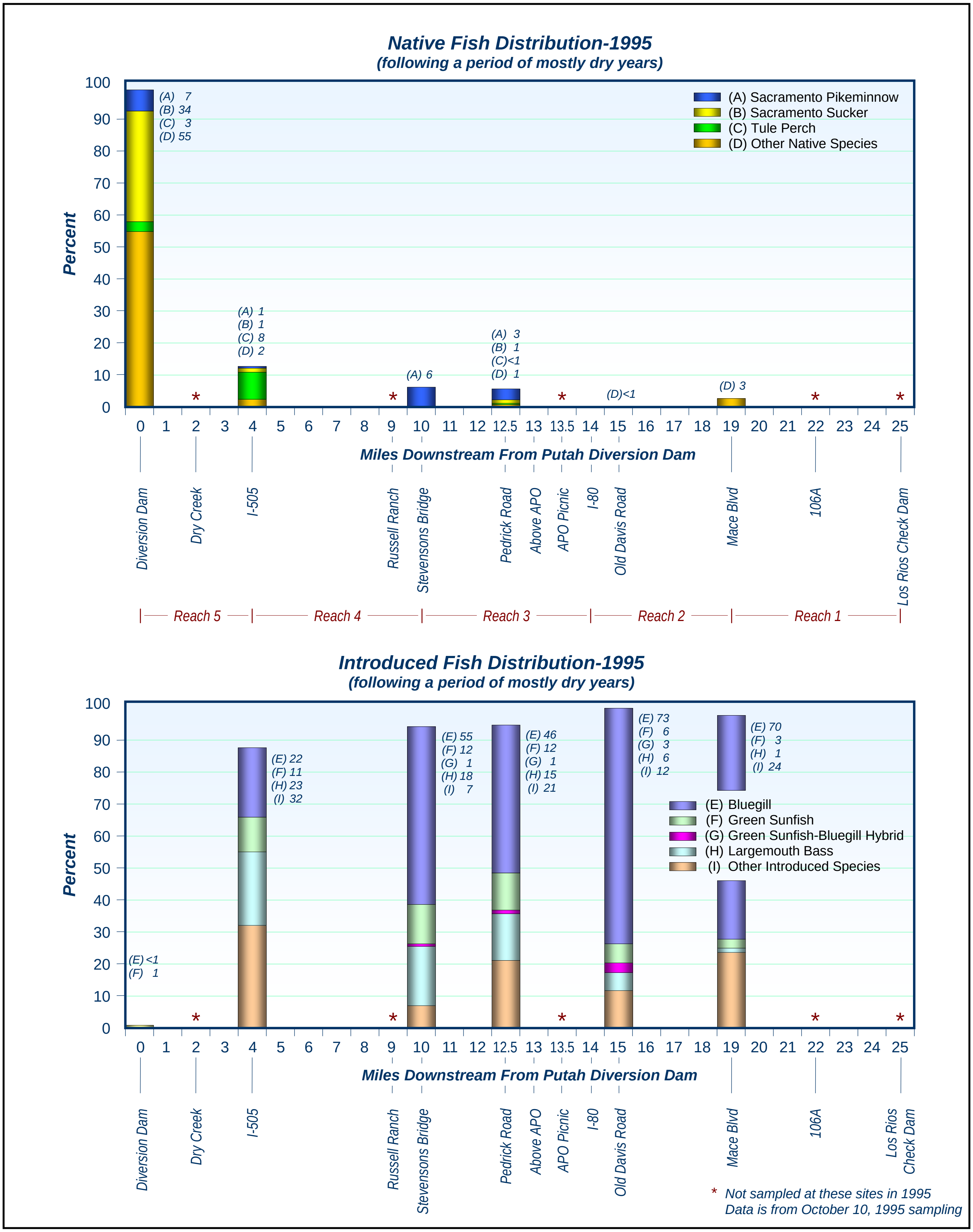


Percentages of Native Fish in Lower Putah Creek Over Time

EXHIBIT 5-7

Exhibits 5-8 and 5-9 show the distribution and proportion of native and non-native fish sampled in lower Putah Creek in 1995 and 1999, respectively. Exhibit 5-10 shows the locations of fish sampling sites from 1991 to present. The fish distribution exhibits highlight the proportion of the common native (i.e., Sacramento pikeminnow, Sacramento sucker, and tule perch) and non-native (i.e., bluegill, green sunfish, green sunfish-bluegill hybrid, and largemouth bass) species that occur most frequently. The years shown are representative of fish population patterns following dry (e.g., 1994) and wet (e.g., 1998) years. In general, native fish species were more numerous in the reaches below the PDD and introduced species were more numerous in the lower reaches. However, in a year (e.g., 1995) following a number of dry years, native fishes were mostly concentrated near the Diversion Dam and the number of native fishes declined sharply a short distance downstream from the Dam. In contrast, introduced non-native fish were abundant and dominated all reaches except immediately downstream of the Diversion Dam. Bluegill was the most abundant fish overall in lower Putah Creek in 1995. Both native and non-native fish were present in generally small numbers in all locations in the creek where they did not dominate.

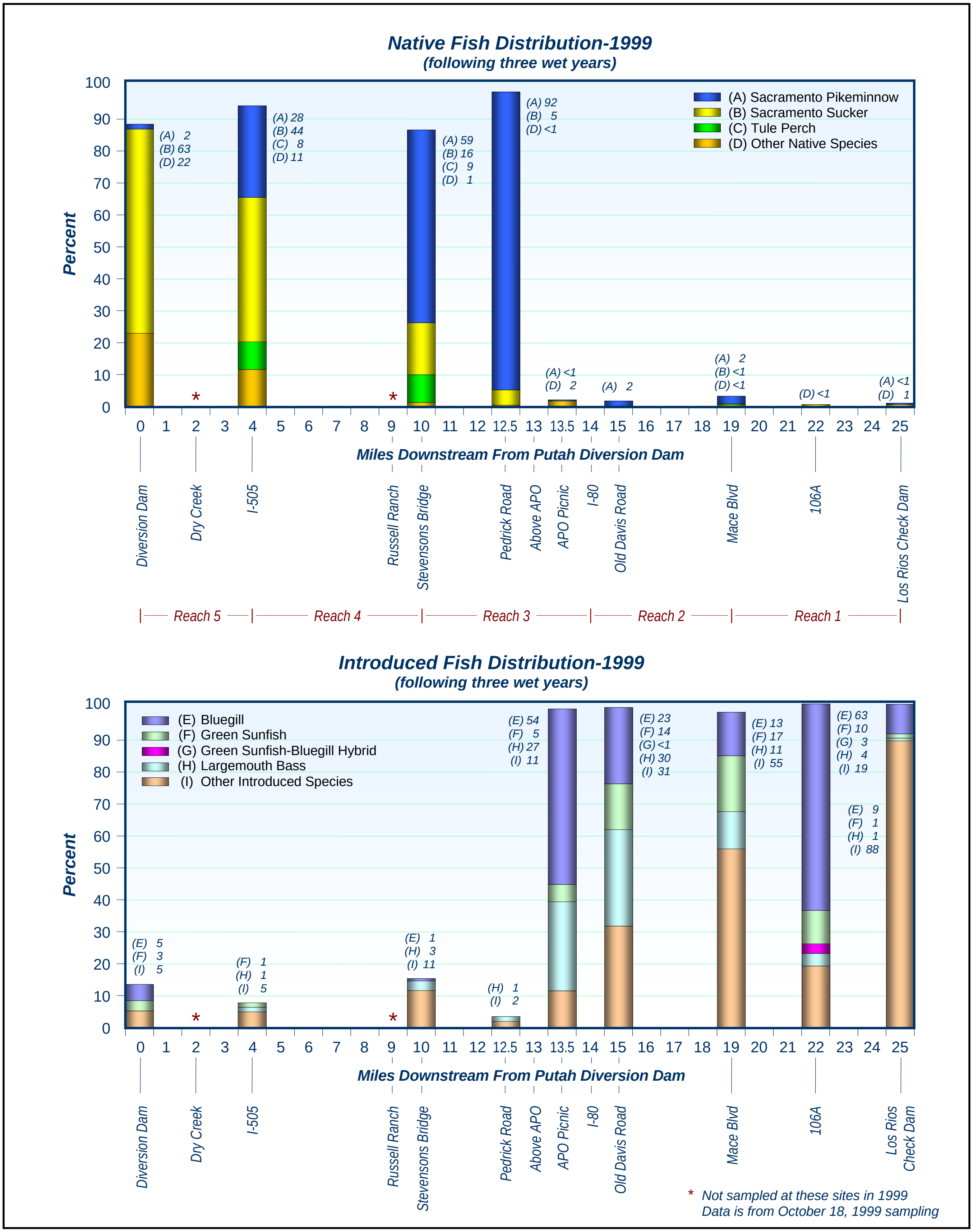
In 1999, representative of a year following a number of wet years, the proportion of native fish was dramatically larger, with native fish, primarily pikeminnow and Sacramento sucker, dominating throughout the upper half of lower Putah Creek, from the Diversion Dam to Pedrick Road. Introduced species were dominant only in the lower half of lower Putah Creek. Again, both native and non-native species were found in all sampling locations. Sacramento sucker was the only native species that was present (although in high numbers only in Reaches 5, 4, and part of 3) throughout the entire creek in most of the years (1991-2002) that were



Source: Moyle et al. 2003; LPCCC 2003; EDAW 2003

Fish Distribution, 1995

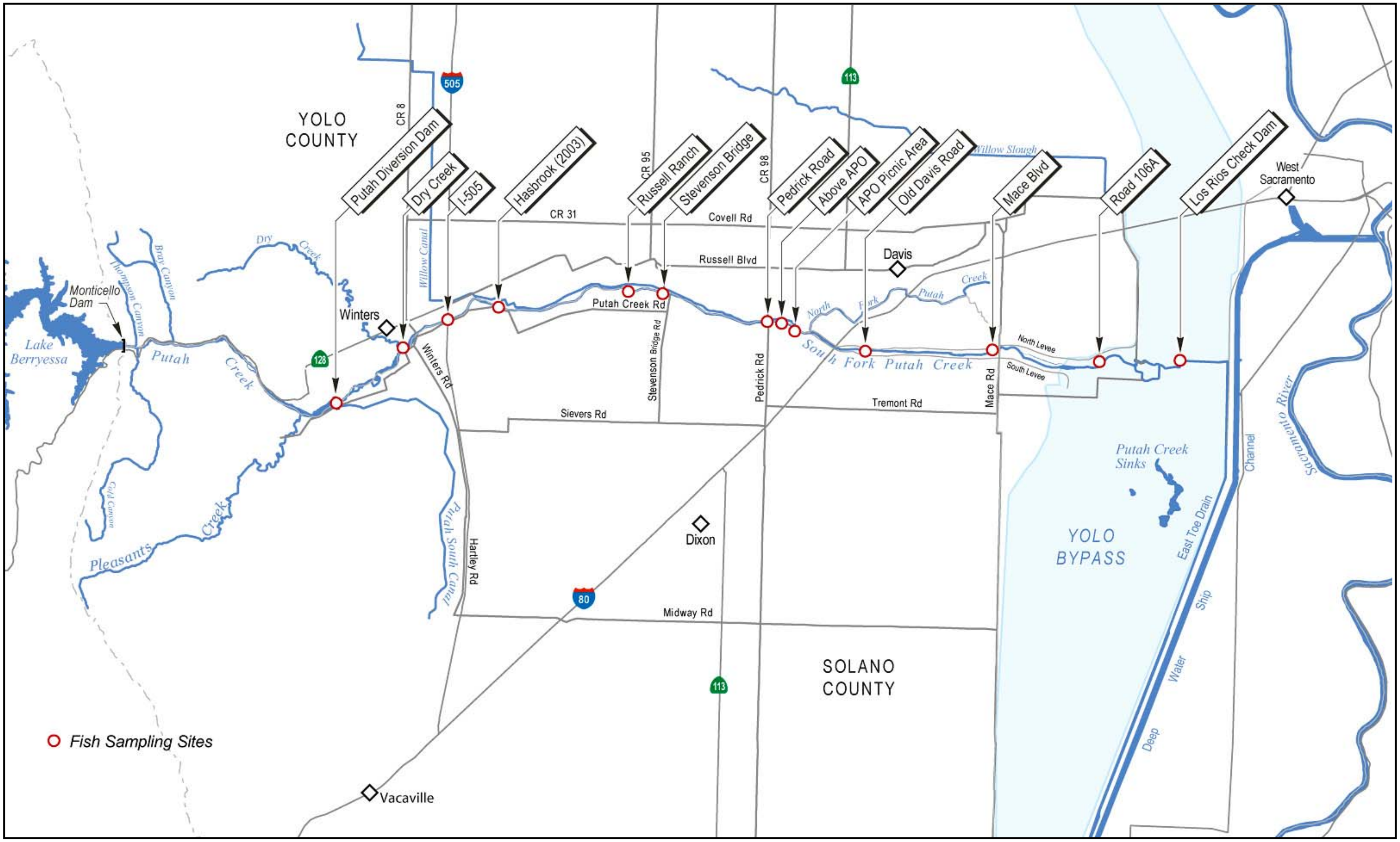
EXHIBIT 5-8



Source: Moyle et al. 2003; LPCCC 2003; EDAW 2003

Fish Distribution, 1999

EXHIBIT 5-9



Source: LPCCC 2003

Fish Sampling Sites

EXHIBIT 5-10

Lower Putah Creek Watershed Management Action Plan
P 1T136.02 2/04

0 2 4 MILES

NORTH

EDAW

sampled. Sacramento pikeminnow was the next most widely distributed native species, occurring in Reaches 3, 4, and 5 in all years, but occurring infrequently in Reaches 1 and 2. Table 5-2 summarizes water-year types in Putah Creek, 1989–2003.

Tule perch was present in all years in Reach 4 (Interstate 505 [I-505] to Stevensons Bridge) and less frequently about 4 miles upstream and downstream of that reach. No other native species were present as frequently as Sacramento sucker, pikeminnow and tule perch. Introduced species that were present throughout the entire creek in most years sampled include bluegill, green sunfish, largemouth bass, and mosquitofish. Native species that were restricted to the upper reach (Reach 5) below the PDD included rainbow trout, restricted to the upper 6 miles (i.e., PDD to Dry Creek) and threespine stickleback, restricted to the upper 4 miles (i.e., I-505 and above). Introduced species that were limited to the lower 6 miles of the creek (i.e., Reach 1, Mace Boulevard and below) include American shad, striped bass, threadfin shad, and yellowfin goby.

Table 5-2
Characterization of Water Years, 1989–2003

Water Year [1]	No. days over 50 cfs	No. days over 1,000 cfs	Water Year Type
1989	12	0	dry
1990	8	0	dry
1991	10	0	dry
1992	8	0	dry
1993	33	2	moderate
1994	0	0	dry
1995	49	5	moderate
1996	77	39	wet
1997	78	42	wet
1998	137	73	wet
1999	88	30	wet
2000	43	0	moderate
2001	28	0	dry
2002	25	0	dry
2003	95	8	moderate

[1] 1994 Water Year begins October 1, 1993, and ends September 30, 1994.

Source: Moyle et al. 2003

Further assessments of native fish distributions are provided, relative to temperature conditions during spawning, below in Section 5.4.3, "Temperature."

5.3.4 PUTAH CREEK WATER ACCORD

This section summarizes the Putah Creek Water Accord signed in May 2000, including the rationale for flow and release requirements specified by the Accord, and stream and fish conditions after the new flows were implemented in 2000. Additional details on the Accord, including the specific details of the flow and release requirements, are provided in Chapter 4, "Geomorphology, Hydrology, and Water Quality."

BACKGROUND

From 1987 to 1992 the worst 6-year drought on record hit the region and the "dry year" release schedule was put into effect in the latter years (Sanford, pers. comm., 2003). Lake Berryessa was drawing down at a rate of about 200,000 net acre-feet per year. Significant riparian diversions - opposed unsuccessfully by the Solano water interests - continued to affect flows in the drought years. In summer 1989, long stretches in the downstream reaches of lower Putah Creek began drying up and major die-offs of fish began occurring (Moyle et al. 1998). The remaining fish were temporarily saved through a combination of interim court-ordered flows; the purchase of water by the City of Davis, Yolo County, and UC Davis; negotiated temporary releases of additional water by the Solano Irrigation District (SID); continued discharge of effluent into the creek by UC Davis; and other emergency measures (Moyle et al. 1998). Attempts to negotiate a permanent solution to the problem failed and on August 15, 1990, the PCC, joined later by UC Davis and the City of Davis, sued SCWA, SID, and other Solano Project member entities for additional water (Moyle et al. 1998, Krovoza 2000). The PCC sought and obtained an injunction briefly increasing releases during summer 1990. Those releases kept some parts of the creek from drying up but the injunction was lifted in fall. As legal maneuvers continued in 1991, most of the lower section of the creek dried up, except for the reach immediately below the Diversion Dam and a few large pools fed by effluent and groundwater. The drought continued in 1992, but water donated by UC Davis and the Alhambra Pacific Company kept the creek flowing. By December 1992, Lake Berryessa had reached its lowest water storage level (Exhibit 4-2). The storage level dropped to 430,000 acre-feet or about 25% of its total capacity. This equaled only about 2 more years of water supply for the water users. The drought finally ended in 1993 and higher flows resumed in the creek (Moyle et al. 1998).

During the Putah Creek Trial in March and April 1996, the plaintiffs sought a dam release schedule based on a model of instream flows for Putah Creek created primarily by Dr. Peter Moyle and Michael Marchetti. The stream flow recommendations from this model had four components: 1) living space flows for the entire creek, 2) resident native fish spawning and rearing flows, 3) anadromous fish flows, and 4) habitat maintenance flows. In an attempt to balance competing demands for water, Judge Park only ordered implementation of the first two components of the stream flow recommendation. The decision was for a 50% increase in the minimum release schedule from the PDD, equal to approximately 10,000 additional acre-feet of water per year. However, the Solano parties appealed the decision (Moyle et al. 1998) and 4 years later the lawsuit was resolved via a settlement agreement (Accord) (Krovoza 2000).

On May 23, 2000, a settlement (the Accord) was reached between the Solano County parties and the Yolo County-based parties. It created a new permanent release schedule that satisfied both parties. Three of the six main elements of the Accord directly affect flows to benefit the creek's fish and the remaining three pertain to management of lower Putah Creek (Krovoza 2000). The Accord elements include:

(1) Flows for resident native fish, which include important spawning and rearing components and guarantee a continuous flow to the Yolo Bypass;

(2) Flows that will attract and support salmon and steelhead;

(3) A drought schedule that provides enough water to maintain Putah Creek as living stream but provides water users relief from other flow requirements;

(4) Creation of the Lower Putah Creek Coordinating Committee (LPCCC);

(5) Habitat restoration and monitoring funds for the creek; and

(6) A term requiring Solano County Water Agency to notify riparian water users of the amount of riparian water available in any given year and to prevent illegal water diversions in excess of the amount of riparian water available.

POST-ACCORD STREAM CONDITIONS

Following the Accord, the new flow schedule went into effect immediately. The new flow schedule is based on a model created by Dr. Peter Moyle and other fish experts, for Putah Creek instream flows that favor native resident and anadromous fishes. (See Table 4-2 in Chapter 4, "Geomorphology, Hydrology, and Water Quality.") Part of the basis for this model is a study on the effects of flow regime on fish assemblages in lower Putah Creek (Marchetti and Moyle 2001), discussed previously in the Subsection, "Fish Distribution in Response to Wet and Dry Year Flow Releases." The first 2 years following implementation of the Accord were moderate (2000) and dry (2001) water years.

Due to favorable hydrologic conditions from at least 2000 to 2002, the flow requirements of the Putah Creek Accord were largely met by natural conditions (i.e., without releasing additional stored water). Key exceptions include the pulse flow releases in fall and spring. During the first few years, the fall pulse flows were largely unsuccessful in attracting upstream migrants. The primary affect of the Accord flows on fisheries in those years may have been from the spring pulse. Fall 2003 appears to be the first evidence that salmon attraction flows, coupled with fortuitous natural runoff events, succeeded in attracting fall migrants. This is described in more detail later in this chapter. Following is a summary of the new flow release schedule.

Release Schedule

This subsection provides a summary of the components and rationale for the new flow regime. The components of the new flow regime are rearing flows, spawning flows, supplemental flows, and drought year flows (Moyle 2002b). Details on the flow release schedule and instream flow requirements are provided in Table 4-2 in Chapter 4, "Geomorphology, Hydrology, and Water Quality."

Rearing Flows

This is a baseline flow regime designed to maintain a year-round living stream from the PDD to the Toe Drain. It is intended to provide cool-water habitat for native fishes for at least several miles below the PDD, even under the worst drought conditions. It also provides enough water to support introduced fishes (e.g., largemouth bass, catfishes, and bluegill) in the lower reaches. These flows overcome past limitations in which the stream dried up during summer in extreme drought years, except for a few large pools and a short section below the PDD (Moyle 2002b).

Native Fish Spawning Flows

Spawning flows consist of a short pulse in February–March, lasting three consecutive days, followed by a month-long release of higher than baseline flows. The purpose of these flows is to provide spawning opportunities for native fishes in winter and spring if there was insufficient rain to provide for them naturally. Native fishes, such as Sacramento sucker, are stimulated to spawn by hydrological changes that deepen spawning riffles and flood shoreline habitat for rearing. The pulse would bring the fish upstream and the increased flows would allow them to spawn and rear. Dr. Moyle predicted that these flows, in combination with baseline rearing flows, would greatly increase the abundance and distribution of native fishes in the creek (Moyle 2002b).

Supplemental (Pulse) Flows

Supplemental flows are designed to primarily benefit the migration of fall-run chinook salmon. The Accord includes a requirement for a minimum flow beginning in November and a 5-day pulse flow to occur at an optimal time (based on monitoring) in November or December to attract and enable adult fall-run chinook salmon to migrate up Putah Creek from the Toe Drain. The Accord also specifies a minimum flow that follows the pulse flow and continues through the end of May. The springtime minimum flows are designed to benefit juvenile salmon for rearing and to enable them to return back to the Toe Drain and sea (Moyle 2002b).

The supplemental flow regime, although designed primarily to benefit salmon, seems to benefit lampreys and may be adequate for rearing juvenile steelhead as well. Adult steelhead may make it up the stream under high winter flows, but it is likely that in most years flows from December to February are too low to attract steelhead, unless water is spilling from Lake Berryessa (Moyle 2002b; Moyle, pers. comm., 2003).

Drought Year Flows

These flows are to be implemented during severe droughts, when all flows but the minimum flows can be eliminated for 2 years. During droughts, normal flow regimes outlined in the subsections above are not in effect every year. Droughts are defined as periods in which the total storage in Lake Berryessa is less than 750,000 cfs on April 1 of any given year. Severe droughts are defined as periods in which Lake Berryessa holds less than 400,000 acre-feet of water on April 1. Under the drought year flow regime, normal flows are implemented in every third year of an extended drought unless the drought is severe. During extended (e.g., 3 or more years) severe droughts, normal flows are not implemented until the first year immediately after Lake Berryessa storage exceeds 400,000 acre-feet.

The drought year flow regime seeks to strike a reasonable balance between human water demands and the minimum needs of fishes during droughts. While the stream and its fish will not receive more than minimum flows during most drought years, periodically they regain priority for water if the drought continues. The drought regime also recognizes that during drought conditions, native fish can persist under minimal flow conditions without reproducing. Native fishes can persist if competition and predation from introduced fishes is limited or if suitable habitat refuges exist for the native fishes (Marchetti and Moyle 2001). Even before the settlement, small numbers of native fishes managed to persist through extreme drought conditions that dried up most of the creek. The minimum flows provided under the new schedule are expected to enable native fishes to have a higher level of persistence than prior to the Accord.

The drought schedule requires that a continuous flow be maintained in the reach from PDD to Interstate 80 (I-80) (a 15-mile stretch) at all times. Thus, the reaches of Putah Creek closer to the Diversion Dam, which are the reaches dominated by resident native fishes, will not go dry, protecting native fish from lengthy droughts. The non-native species, which tend to dominate in the reaches nearer to and below I-80, will not receive as much protection from the drought year flow schedule. However, introduced fish may repopulate those reaches from upstream populations following the end of drought cycles (Moyle 2002b).

FISHERIES AFTER WATER ACCORD (2000 TO PRESENT)

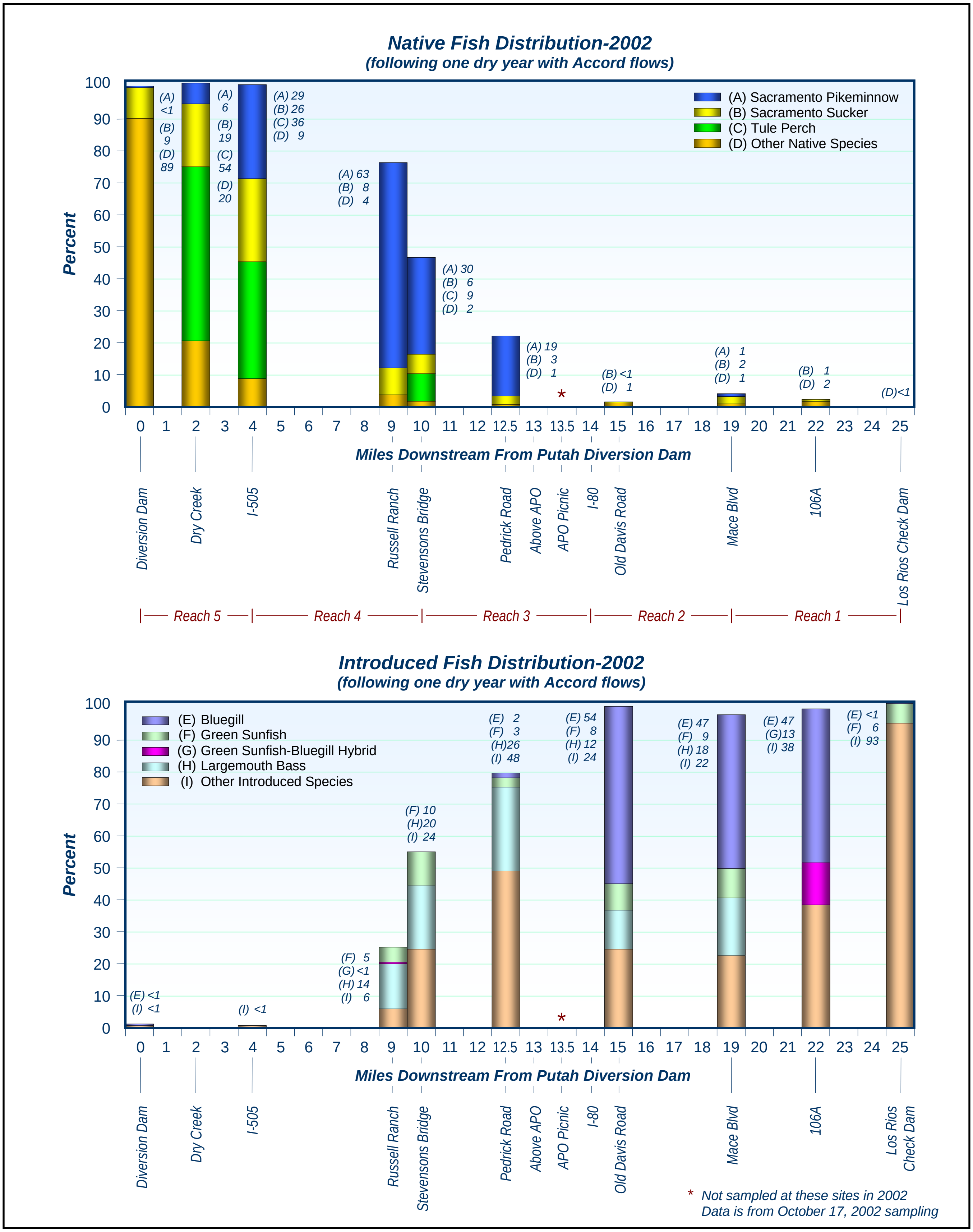
This subsection describes lower Putah Creek fisheries in the nearly 4 years following implementation of the Putah Creek Accord flow schedule. The description is based on observations by Dr. Moyle, Patrick Crain, and others, and on the most recent available data (Moyle et al. 1998; Moyle 2002b; Moyle et al. 2003; Moyle and Crain 2003; Marchetti and Moyle 2001). In addition to the assessments provided in this subsection, native fish distributions are preliminarily assessed relative to temperature conditions during spawning in the Subsection, “Temperature,” later in this chapter.

Thus far, fisheries sampling data through 2002 have been analyzed following implementation of the Accord flows. However, based on these initial data and other observations, it appears that the distribution and abundance of native fish in lower Putah Creek may be substantially greater following dry years with the new Accord flow schedule than following dry years under the old flow regime. Exhibit 5-11 shows the distribution of native and introduced non-native fish in lower Putah Creek in 2002, following a dry year (Exhibit 5-6). Exhibit 5-7 shows the percent of all native fish sampled throughout lower Putah Creek between 1993 and 2002. The percent of native fish sampled throughout lower Putah Creek in fall 2002 was 46%, much higher than during the mid-1990s. However, while the mid-1990s samples were taken during a period of several mostly dry years, the Accord period dry years thus far are following a period of mostly wet years, so it may be too soon to draw conclusions stating that the Accord flows were a primary reason accounting for the higher proportion of native species. This is because fish populations can increase or decrease over a period of years in response to changing flow patterns.

Exhibit 5-11 shows a high proportion of native species still present 10 miles downstream of the PDD. The distribution of native fish was much more extensive than in 1995 (Exhibit 5-8), following a period of mostly dry years. In 1995, native fish were concentrated near the Diversion Dam, and the abundance of native species was very low downstream of the dam. Introduced fish dominated about 90% of the creek. In addition to this, downstream pools at Stevensons Bridge and Pedrick Road that had relatively few native fish during pre-Accord conditions now have an abundance of native fish. Even in areas that remain dominated by warm-water non-native fishes there are now more native fish than there were prior to the Accord. These results may be beginning to confirm Dr. Moyle's predictions (Exhibit 5-12) of an increase in the distribution of native species downstream of the PDD following implementation of increased flow releases, in comparison to the limited distribution characterizing native fish populations in the creek prior to the Accord, between 1980 and 1995 (Exhibit 5-5).

It is probably premature to conclude that the regulated spring pulse flows likely made a difference in enabling increased spawning by native resident fishes. During the two dry years (2001 and 2002) following implementation of the Accord flow schedule, with regulated spring pulse flows in place, Sacramento pikeminnow, Sacramento sucker, and tule perch (all common native resident fishes) all spawned (Crain, pers. comm., 2003). However, the degree to which the regulated spring flows made a difference in enabling the spawning is uncertain, since rising groundwater also contributed substantially to the spring flows during this period (Sanford, pers. comm., 2003). Also, some spawning by native fish did occur in dry years prior to provision of regulated spring pulse flows, such as in 1994 (Salamunovich, pers. comm., 2003).

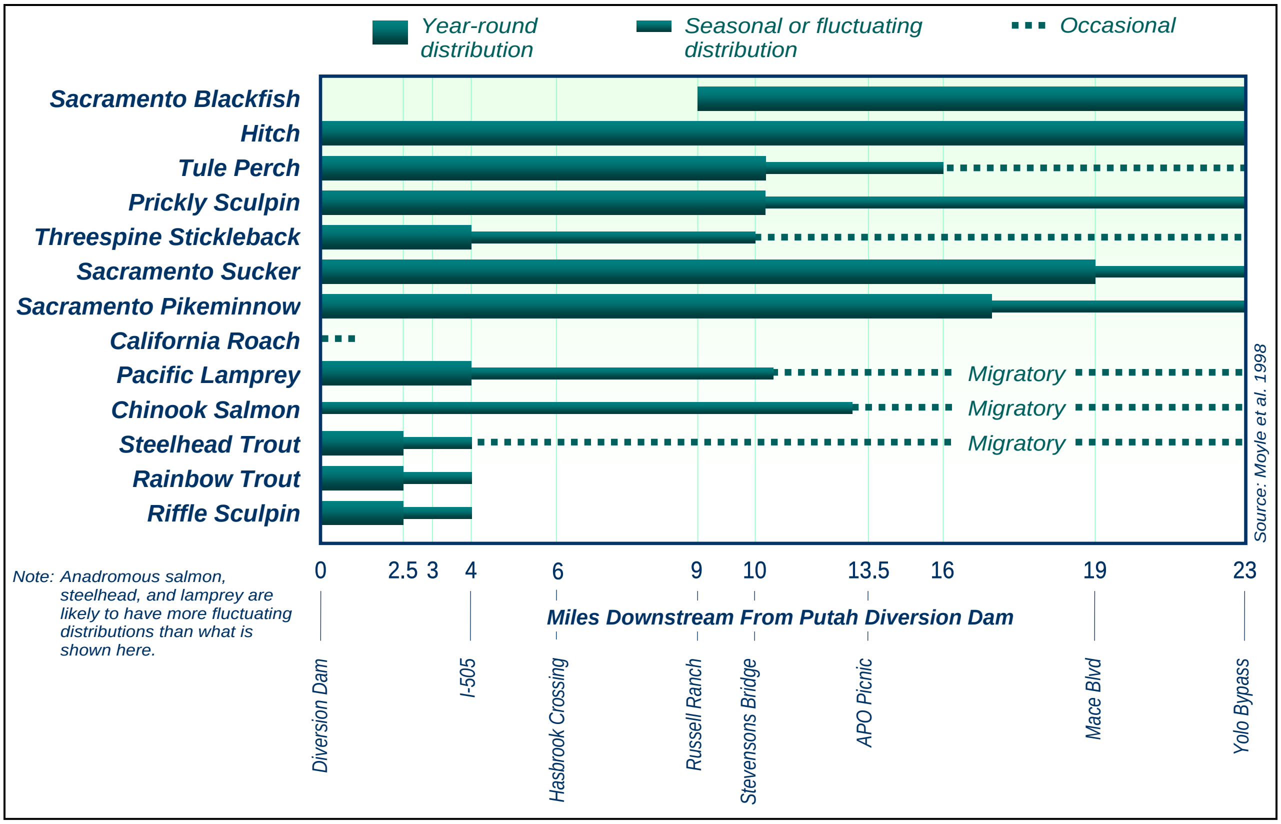
The most recent result of the new flow releases is that fall-run chinook salmon are migrating up the creek to spawn. An estimated 70 adult fall-run chinook salmon migrated up lower Putah Creek in fall 2003, resulting in the biggest salmon run in the past 40 or more years (Moyle, pers. comm., 2003; PCC 2003). The 2003 run followed 3 years of few to no salmon found on the creek despite implementation of the pulse release and other supplemental releases, and removal of the check boards at Los Rios Check Dam in the Yolo Bypass, all to attract and enable the salmon to migrate up into Putah Creek from the Toe Drain. For the first 3 years after the new release schedule was implemented, there were no reported observations of chinook salmon spawning, yet there were small numbers of juvenile salmon



Source: Moyle et al. 2003; LPCCC 2003; EDAW 2003

Fish Distribution, 2002

EXHIBIT 5-11



Predicted Native Fish Distribution with New Flow Releases — EXHIBIT 5-12

sampled that may have resulted from salmon spawning in the creek (LPCCC 2003) or that may have originated from the release of small numbers of classroom-reared fish in Winters (Crain, pers. comm., 2003).

Then, on October 16, 2003, a 30-inch adult chinook salmon was captured by fish biologists with Thomas R. Payne and Associates below the PDD, and several test redds were observed (Salamunovich, pers. comm., 2003) (Exhibit 5-2). The known fish passage barriers at the time were large and seemingly insurmountable. Los Rios Check Dam downstream in the Yolo Bypass was still closed and a 6- to 8-foot-high beaver dam was present one-quarter mile downstream of Road 106A (Exhibit 5-10). From November 30 to December 5, following removal of Los Rios Check Dam, flow releases were increased to support salmon migration. The attraction flows lasted long enough to bring some fish up from the Sacramento River (Moyle, pers. comm., 2003). On December 8, Tim Salamunovich of Thomas R. Payne and Associates reported that his crew observed additional salmon and redds in the creek (Salamunovich pers. comm., 2003). On December 10, Dr. Moyle and his associate, Pat Crain, surveyed the creek by canoe from the PDD to Winters, in response to Tim Salamunovich's reports. Dr. Moyle reported the following:

> I am pleased to report that that last week's augmented flows to Putah Creek designed to bring spawning chinook salmon up the creek, worked this year. The flows are down again, but the attraction flows lasted long enough to bring some fish up from the river. This afternoon (10 December), Pat Crain and I canoed from the Putah Creek Diversion Dam downstream to Winters to look for salmon. We were alerted to their presence by Tim Salamunovich (Thomas R. Payne and Associates) whose crew was working on the creek and reported seeing salmon and their redds on December 8. Below the diversion dam, we talked to an angler who told us he had seen about six salmon in the concrete pool where the water from the creek is released from the dam. Sure enough, we could see at least 4 salmon cruising around, a large (ca. 20 lbs) bright red male and three females. No place to spawn there, of course. On the path leading down to the creek we found the head of a salmon, with a fishing hook and line still attached to its mouth. I assume such fishing is legal there, as long the fish is caught in the mouth and not snagged. Still, it would be nice to see the salmon left alone for a few years, to see if we could build up populations. In the gravelly areas below the dam, we spotted 4 more salmon and a couple of redds in water about 25–30 cm deep. A female was sitting on one redd, her tail white from having scraped away the skin while digging her nest. For the next mile, there seemed to be redds in most of the small areas where there was large gravel. We counted eight redds altogether although some were in such shallow water (<20 cm) they had presumably been abandoned when the flows dropped. We saw only four salmon and they were very skittish, bolting into cover at our approach. One large male we observed on a redd from some distance away because its dorsal and tail fins were out of the water. After this, there was a long stretch of either large pools or shallow sandy runs, with no gravels suitable for spawning. In the big pool area, there was a large beaver dam that was being actively managed by beaver and would presumably be a barrier to movement under the present flows, but passable under the earlier releases. More gravel was encountered at the mouth of Dry Creek and we observed two more redds there, one with a female still in attendance, despite shallow water (ca. 25 cm). Altogether we saw 13 live salmon and 12 redds, which suggests that more salmon are or were present in this reach. We have not yet checked out areas downstream of Winters but there is a report of at least one salmon below the Stevenson Road bridge. Thus it is likely the salmon are spawning in most areas where there is suitable gravel. Great day to be on the water, cool, a few sprinkles of rain, complicated clouds, and lots of birds. (Moyle and Crain 2003).

On December 17 and 18, Dr. Moyle and Pat Crain again surveyed the creek from the PDD to I-80 and found over 40 redds at just over 30 locations and observed a total of at least 19 adult chinook salmon (Moyle and Crain 2003; Moyle, pers. comm., 2003). Dr. Moyle estimated that the salmon run consisted of about 70 spawners.

> It looked to Pat and I that the salmon had used virtually all of the gravel patches with the right combination of coarse gravel, fast water, and depth. As we canoed down stream we could look ahead of us and often predict a redd location, if a salmon fin did not give it away first (Moyle and Crain 2003).

Moyle and Crain continued the survey by walking and wading from I-80 to Old Davis Road, but did not see any redds, nor suitable gravel except in some bars high above the flow (Moyle, pers. comm., 2003). An analysis of hydraulic conditions and substrate types in lower Putah Creek was conducted by hydrologist Gus Yates in 2003, and the results of his analysis are summarized in Section 5.4, "Spawning Habitat in Lower Putah Creek." Yates also determined locations of suitable spawning habitat for the native fishes of lower Putah Creek, including fall-run chinook salmon, based on criteria provided by Dr. Moyle. The predicted suitable spawning locations for salmon are indicated in Exhibit 5-13, along with the locations of redds surveyed in 2003. Table 5-3 summarizes the hydraulic and substrate characteristics of the redd sites. The vast majority, 24 (60%) of the 40 redds observed and reported by Moyle and Crain (2003) were located in gravel substrate under a maximum of 14 to 24 inches of water. An additional eight (20%) redds were located in patchy gravel under a maximum of 16 to 22 inches or water, and three (13%) redds were in sand and gravel under a maximum of 17 to 21 inches of water. Only two redds were located in sand and one was located in claypan with no overlying material. However, many redds located in gravel and other substrates were placed down into the clay substrate (Moyle, pers. comm., 2003). A discussion of redd occurrences compared to predicted suitable habitat is found in the subsection 5.4, "Spawning Habitat in Lower Putah Creek," below.

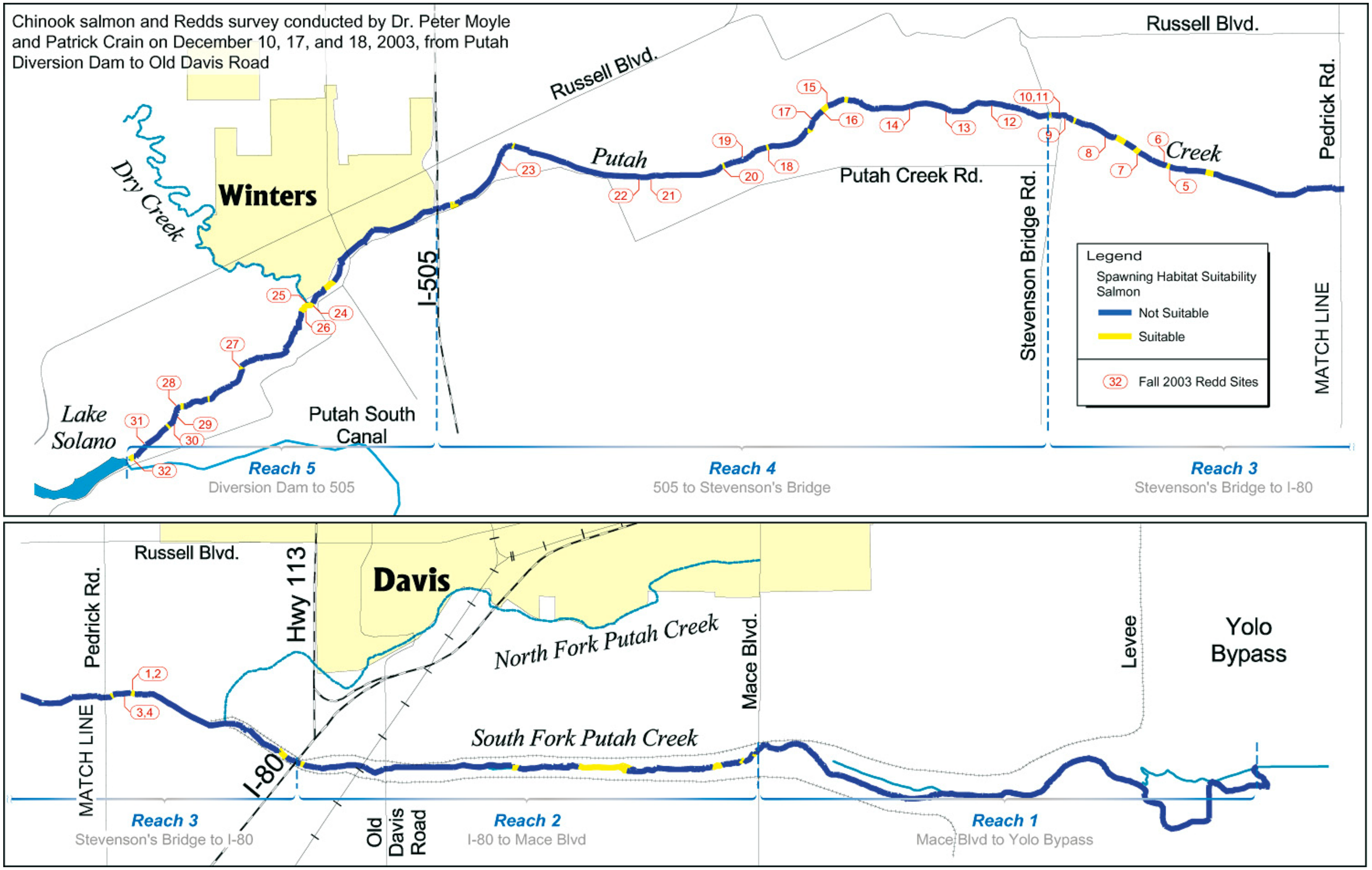
The lack of suitable gravel spawning sites is a constraint for salmon spawning. The observations of salmon at the concrete pool below the PDD indicated that most or all spawning locations downstream had likely been utilized by the migrating salmon and further confirmed Dr. Moyle's determination that Putah Creek is currently limited by a lack of suitable gravel substrate for salmon spawning (Marovich, pers. comm., 2003).

Adult steelhead have yet to be observed in the creek. Based on 2003 electrofishing surveys, rainbow trout are only routinely found in the creek from the PDD to Dry Creek. The lowest point at which trout have been observed in summer is the Hasbrook crossing about 6 miles downstream. This indicates that suitable habitat may be favorable to salmonids, 2 miles farther downstream from the PDD than previously thought (Marovich, pers. comm., 2003).

Table 5-3
Characteristics of Fall 2003 Salmon Redd Sites in Lower Putah Creek

Substrate	Hydraulic Condition						All Hydraulic Types	
	Pool		Riffle		Run			
	# Redds	Maximum Water Depth	# Redds	Maximum Water Depth	# Redds	Maximum Water Depth	# Redds	Maximum Water Depth
Claypan	0	—	0	—	1	12 in.	1	12 in.
Gravel	3	17 in.	8	16–21 in.	13	14–24 in.	24	14–24 in.
Patchy gravel	6	16–22 in.	0	—	2	16–19 in.	8	16–22 in.
Sand	2	17 in.	0	—	0	—	2	17 in.
Sand and gravel	2	17–18 in.	0	—	3	17–21 in.	5	17–21 in.
Total	13	16–22 in.	8	16–21 in.	19	12–24 in.	40	12–24 in.

Data Sources: Moyle and Crain 2003; Yates 2003.



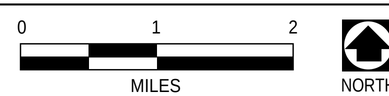
Source: Moyle and Crain 2003; Yates 2003

Fall Run Chinook Salmon Redd Sites Observed in 2003 Compared to Predicted Suitable Spawning Habitat

EXHIBIT 5-13

Lower Putah Creek Watershed Management Action Plan

P 1T136.02 12/03



EDAW

5.4 Spawning Habitat in Lower Putah Creek

This subsection summarizes information primarily from a lower Putah Creek spawning habitat and gravel study conducted by hydrologist Gus Yates (2003), along with an assessment by EDAW biologists and water quality specialists of temperature data provided by SCWA (2003). The main purpose of Yates' study was to document the distribution and texture of unconsolidated sediment along the bed of lower Putah Creek so that assessments could be made regarding the adequacy of existing streambed gravels to support present or future fish populations. This subsection includes the following components:

- spawning criteria for native fish, including trout and steelhead, chinook salmon, Pacific lamprey, and native resident fish;
- hydraulic conditions, including pool, riffle, and run characteristics and distribution;
- potential spawning habitat for native fish; and
- water temperature characteristics related to spawning.

5.4.1 Spawning Criteria for Native Fishes

All native fishes in lower Putah Creek require certain hydraulic conditions for spawning, and most require a gravel substrate. However, the hydraulic requirements as well as the gravel texture and thickness requirements vary among species. Hydraulic conditions refer to habitat type, flow, and water depth. In the Yates (2003) spawning and gravel study, spawning requirements were grouped into several categories based on known or suspected similarities in spawning requirements. Table 5-4 provides the best available information characterizing the substrate criteria, hydraulic criteria, and other spawning habitat requirements of native anadromous and resident fishes as compiled by Dr. Peter Moyle (Moyle 2002a, Yates 2003).

In general, much more information is available for salmonids than for other native fish. Native salmonid species in lower Putah Creek include fall-run chinook salmon, rainbow trout, and steelhead. The fall-run chinook salmon and steelhead are anadromous. Gravel texture and redd size for these species vary somewhat based on fish size. A redd is a fish nest built in gravel substrate. In general, the female excavates a depression in the gravel and deposits her eggs. A male or several males then fertilize the eggs and the female then covers the eggs with gravel.

Native species also include Pacific lamprey, an anadromous species, and resident fish including primarily cyprinids (Sacramento blackfish, hitch, and Sacramento pikeminnow), catostomids (Sacramento sucker), gasterosteids (threespine stickleback), and embiotocids (tule perch). Tule perch bear live young, and blackfish and sticklebacks spawn on vegetation. As a result, sediment texture is not important for these species; however, suitable hydraulic conditions must still be present. In general, native fish species appear to be less particular about water depth than flow and substrate conditions. Native species are likely to spawn using the best available site, even if it is less than optimal (Yates 2003). Water temperature is an important factor for spawning, but temperature data for lower Putah Creek are limited and were not included as part of the analysis for potential spawning habitat in Yates' study.

Table 5-4
Spawning Site Criteria for Native Fish in Lower Putah Creek

Fish	Hydraulic Conditions			Substrate Conditions		Redd	Spawning Temperatures
	Type	Depth (ft)	Velocity (ft/s)	Gravel Texture	Gravel Thickness		
Rainbow trout Steelhead Chinook salmon	Riffles or pool tailouts preferred	0.3–4.9 (trout and steelhead) 0.8–3.3 (salmon)	0.6–5.1 (trout and steelhead) 1.0–2.6 (salmon)	Fines <0.04 in (<1 mm) less than 14% by weight Fines <0.4 in (<10 mm) 12-40% by weight D50 less than 10% of fish length (less than 4% of length preferred) 1-10 in (25-250 mm) typical grain size (large) 0.4-5.0 in (10-130 mm) typical grain size (small)	>12 inches (?) Perceptible flow through gravel	Redds dug by agitating gravel to create a depression and decrease percentage of fines Preferred gravel size related to adult fish size.	10-15°C (50-59°F) 5-19°C (41-66.2°F)
Pacific lamprey	Riffles or pool tailouts preferred	1.0–2.7	0.4–2.8	Similar to salmon, but not as particular	Unknown	Redds dug by individually moving larger stones to downstream edge of depression	12-18°C (53.6-64.4°F)
Sacramento blackfish	Pool edges	>2	Slow	Unimportant	Unimportant	Sticky eggs deposited on roots and vegetation	12-24°C (53.6-75.2°F)

Table 5-4
Spawning Site Criteria for Native Fish in Lower Putah Creek

Fish	Hydraulic Conditions			Substrate Conditions		Redd	Spawning Temperatures
	Type	Depth (ft)	Velocity (ft/s)	Gravel Texture	Gravel Thickness		
Sacramento pikeminnow	Riffles	>1	1.0–2.5 (?)	0.4–2.0 in (10–50 mm) dominant size	Unimportant	Clean off surface and lay sticky eggs	15–20°C (59-68°F)
Hitch	Riffles	>1	1.0–2.5 (?)	Clean, fine-to-medium gravel (0.4–2.0 in (10–50 mm) dominant size)	Unknown	Eggs not adhesive but sink into gravel	14–18°C (57.2-64.4°F)
Sacramento sucker	Riffles	>1	1.0–2.5 (?)	0.4–2.0 in (10–50 mm) dominant size	Unimportant	Sticky eggs adhere to gravel or debris	12–18°C (53.6-64.4°F)
Threespine stickleback	Pools and backwaters	0.7-3	Slow	Soft or mixed bottom material	Unimportant	Build nests of vegetation	Below 23–24°C (73.4-75.2°F)
Tule perch	Slow-moving waters and backwaters		Slow	Unimportant	Unimportant	Females give live birth in area with dense plant cover	Below 22°C (71.6°F)

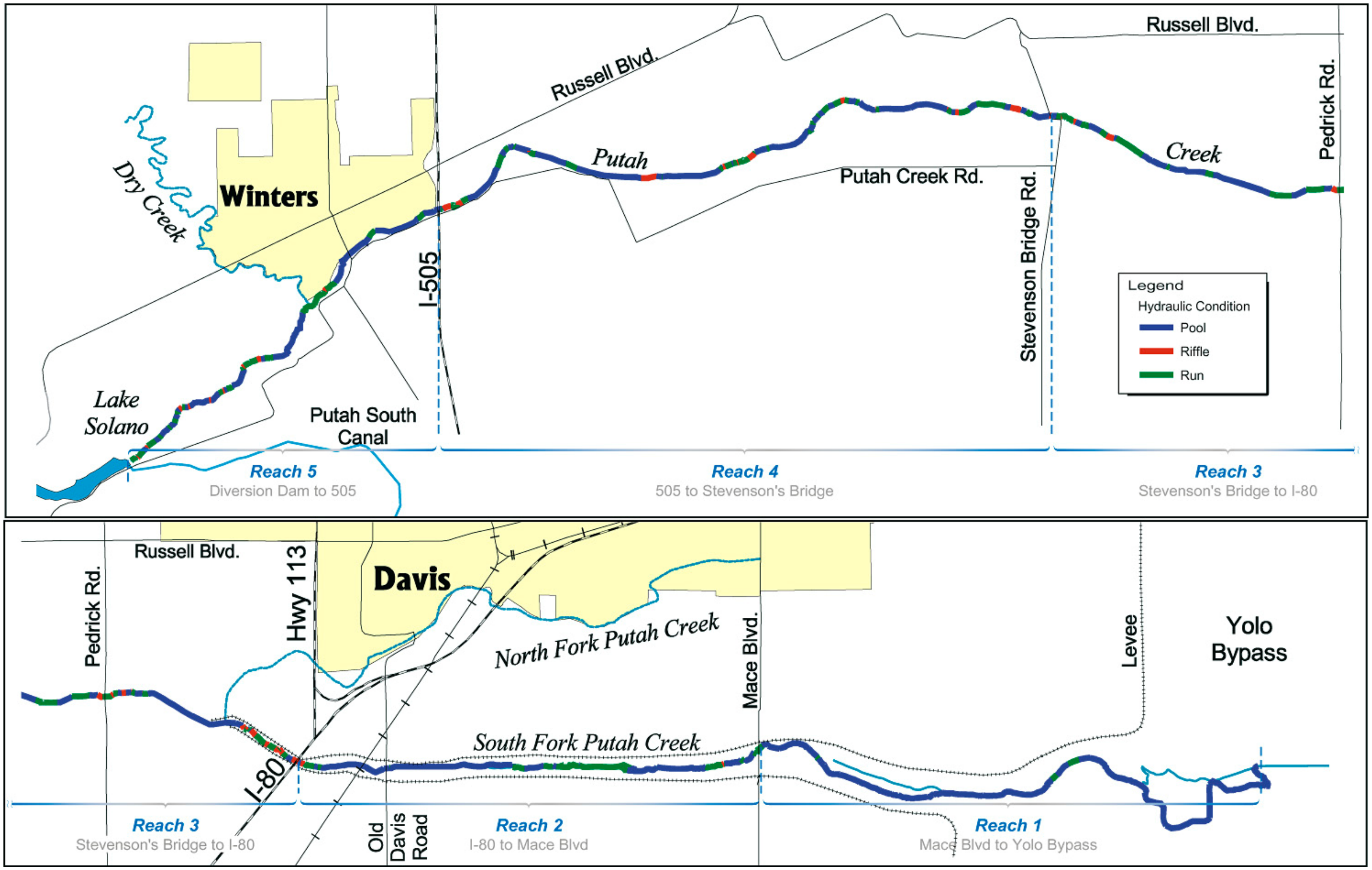
Sources: Moyle 2002, Kondolf 2000, Yates 2003

Based on the data available, an assessment is of the effects of temperature on suitable spawning habitat for native fish is provided in Subsection, "Temperature," below.

Fish species that spawn on gravels with moderate flow velocity (i.e., 1.0–2.6 ft/s) include pikeminnow, sucker, hitch, salmon, steelhead, and rainbow trout (Table 5-4). These species have the following preference ranges for gravel size/texture (diameter): 0.4–2.0 inches (10–50 millimeters) for pikeminnows, suckers, and hitch; and 1–10 inches (25–250 millimeters) for salmon, steelhead, and rainbow trout (Table 5-4). All species prefer fairly clean gravel. Studies of salmonid spawning in other areas have found salmon prefer to have no more than 10% of the gravel (by weight) be characterized by fine material measuring less than 1 millimeter in diameter, to ensure adequate flow and oxygen delivery through the gravels. Fine material less than about 0.4 inch (10 millimeters) can also block the emergence of salmon fry from the gravels, especially if the fine material is deposited after spawning has occurred. A few observations of natural gravels used by salmon to build redds indicate that material smaller than 0.4 inch (10 millimeters) typically comprises between 14% and 40% of the redd (Kondolf 2000). In lower Putah Creek, currently available gravels generally are less than 3 inches in size; however, a mixture of gravels ranging from 1 to 10 inches are probably more desirable for salmon spawning (Moyle, pers. comm., 2003).

5.4.2 HYDRAULIC AND SUBSTRATE CONDITIONS

A characterization of pools, riffles and runs was conducted during summer surveys, when flows were between 20 and 43 cfs (Yates 2003). The distribution of those low-flow hydraulic conditions along lower Putah Creek are shown in Exhibit 5-14 (Yates 2003). The distribution of substrate types is provided in Exhibit 5-15 (Yates 2003). The maps are divided into two segments: the reach from PDD to Pedrick Road (top of map) and the reach from Pedrick Road to the Yolo Bypass (bottom of map). Note that some of the shortest segments may not be visible at the scale of the exhibits. Table 5-5 shows the total length in river miles occupied by pool, riffle, and run conditions subdivided by substrate types (Yates 2003). Clay-silt (claypan) is likely the underlying bed material in most creek locations. However, it is overlain by unconsolidated sand and gravel along most of the creek (Yates 2003). In Reach 5, between PDD and I-505, the substrate is mostly gravel or a mixture of sand and gravel, with some exposed claypan. In Reach 4, from I-505 to Stevensons Bridge, the substrate along about half of the length is patchy gravel with claypan exposed between patches. The remainder of the reach is characterized by a gravelly substrate with some sand mixed in. From Stevensons Bridge to the split with the north fork of Putah Creek just upstream of I-80, in Reach 3, the substrate is mainly a mixture of sand and gravel. From the north fork split to Mace Boulevard (Reach 2), the substrate varies and includes all eight substrate types. Below Mace Boulevard, the substrate is mostly exposed claypan with some patches of a sand and gravel mixture (Yates 2003).



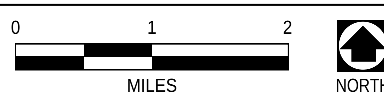
* Hydraulic condition determined during summer surveys when flows were 20–43 cfs.

Source: Yates 2003

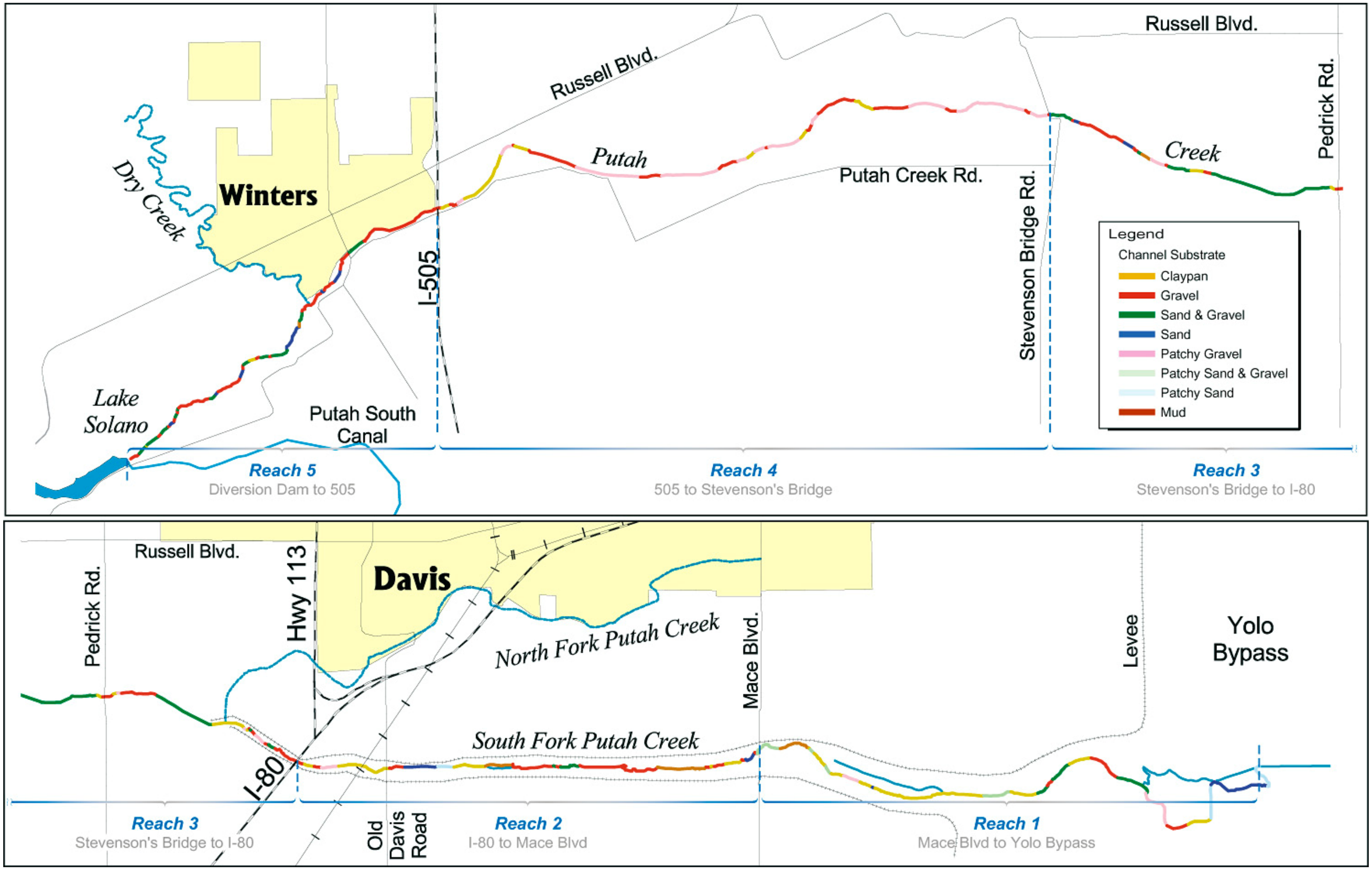
Distribution of Low-Flow* Hydraulic Condition

EXHIBIT 5-14

Lower Putah Creek Watershed Management Action Plan
P 1T136.02 08/03



EDAW



Source: Yates 2003

Distribution of Channel Substrate Type

EXHIBIT 5-15

Lower Putah Creek Watershed Management Action Plan

P 1T136.02 08/03

NORTH

EDAW

Table 5-5 Cumulative Length of Combinations of Hydraulic Condition and Substrate along Lower Putah Creek				
	Hydraulic Type (in miles)			
	Pool	Riffle	Run	Total
Clay-silt ("claypan")	4.09	0.27	0.55	4.91
Gravel	3.76	1.01	3.28	8.06
Sand and gravel	2.97	0.00	1.12	4.09
Sand	1.57	0.00	0.14	1.71
Mud	1.13	0.00	0.00	1.13
Patchy gravel	3.28	0.04	0.72	4.05
Patchy sand and gravel	0.55	0.00	0.10	0.65
Patchy sand	0.71	0.00	0.00	0.71
Total	18.07	1.33	5.91	25.30
Source: Yates 2003				

POOLS

Pools are areas where the creek is deep and flows are slow moving. Pools occupy about 18 miles (72%) of the creek, the largest percentage of the creek's length. About 7.5 miles (42%) of the cumulative pool length in lower Putah Creek are characterized by a clay-silt (claypan), sand, mud, or patchy sand substrate. An additional 6.7 miles (37%) of pools are characterized by a gravel or sand and gravel substrate, and the remaining 3.8 miles (21%) of pools are characterized by patchy gravel or patchy sand and gravel. Beaver dams, especially in dry years, can dramatically increase pool habitat. By 1992, following several dry years, roughly 90% of the creek between PDD and river mile 0.0 was pool habitat largely caused by over 30 beaver dams. By the late 1990s, most of the beaver dams had washed out and the number of dams has remained relatively unchanged since that time (Sanford, pers. comm., 2003).

RIFFLES

Riffles are shallow areas extending across a relatively steeper sloping streambed such that water flows relatively swiftly across the streambed and makes a rushing sound (Yates 2003). Riffles are relatively short and occupy only about 1.3 miles, or 5% of the creek, but they are scattered throughout Reaches 3, 4, and 5 between PDD and I-80. They are scarce downstream of I-80. The vast majority of the cumulative riffle length in lower Putah Creek, 1.0 mile (75%) is characterized by a gravel substrate, with an additional 0.04 mile (3%) characterized by patchy gravel. The remaining 0.27 mile, or 20% of riffles, is characterized by a clay-silt (claypan) substrate.

RUNS

Runs are relatively shallow portions of a stream that are characterized by moderate velocities, a fairly smooth surface, and generally non-turbulent flow. A run is usually too deep to be considered a riffle and too shallow and fast to be considered a pool (Yates 2003). Runs are variable in length and not consistently sequenced with either pools or riffles. Runs occupy about 6 miles, or 23% of the creek length (Yates 2003). The vast majority, or 4.4 miles (74%), of the cumulative run length in lower Putah Creek are characterized by a gravel or sand and gravel substrate. An additional 0.8 mile (14%) of runs is characterized by patchy gravel or patchy sand and gravel. The remaining 0.7 mile (12%) of runs is characterized by a clay-silt (claypan) or sand substrate.

Hydraulic conditions change with increasing flow. Surveys for hydraulic conditions were completed by Gus Yates during the summer when flow was supplied by steady releases from the PDD. Flows ranged from 20 to 43 cfs, depending on the month and location of the survey. Flows during the spawning season (generally winter through spring) are often higher, with correspondingly greater width, depth, and velocity, depending on runoff events and especially whether Lake Berryessa is spilling. The relative proportions of increase in width, depth, and velocity depend on channel geometry at a given site. Rating curves relating each of these variables to flow have been developed for 12 sites by SCWA and reveal general patterns. These sites are almost all located in runs where flow is relatively narrow, the channel is neither deep nor shallow, and the current is swift but not turbulent. These characteristics fit the spawning site suitability criteria for most of the fish species and the flow-depth-velocity relationships at the gauge sites. They are therefore fairly representative of conditions present at many of the potential spawning sites (Yates 2003).

5.4.3 TEMPERATURE

This subsection includes an assessment of lower Putah Creek water temperature conditions based on fish spawning habitat requirements reported by Dr. Moyle, (Moyle 2002a), and temperature information provided by the Solano County Water Agency (SCWA 2003). Chapter 4, “Geomorphology, Hydrology, and Water Quality,” includes a discussion of additional temperature data for the peak summer conditions. Water temperature is a critical component of spawning requirements. For instance, if spawning conditions are all suitable except for water temperature, a species may still not spawn. Water temperature requirements for spawning vary among species. However, many different native fish species have similar temperature requirements for spawning. Most native species generally spawn during winter and spring. Fall-run chinook salmon are the exception because they spawn primarily in the fall (late-September to December). Suitable spawning temperatures for native species addressed above are as follows (Table 5-4): steelhead/rainbow trout (50–59°F), fall-run chinook salmon (41–66.2°F), Pacific lamprey (53.6–64.4°F), Sacramento blackfish (53.6–75.2°F), Sacramento pikeminnow (59–68°F), hitch (57.2–64.4°F), Sacramento sucker (53.6–64.4°F), tule perch (below 71.6°F), and threespine stickleback (below 73–75°F) (Moyle 2002).

April is considered to be representative of an important seasonal period when many of the native fish species are actively spawning in lower Putah Creek (Crain, pers. comm., 2003). Exhibit 5-20 shows the monthly average maximum and average hourly temperatures recorded during April, based on 1997 and 1999–2002 data provided by SCWA (2003) at sites downstream of the PDD. The data indicate that the creek water gradually increases in temperature as it moves downstream, rising by about 15°F from 49°F to 63°F by the time it has flowed to the Stevensons Bridge area. The creek water temperature does not rise much more as the water continues downstream to the Yolo Bypass. There is also very little difference (i.e., approximately 2 to 3°F) between the average daily temperature and the peak afternoon temperature. Groundwater, which contributes up to a quarter of the total flow, may also affect the water temperature in some years (Sanford, pers. comm., 2003).

Based on the limited available data, water temperatures in April appear to generally reach or exceed the upper range of suitable spawning conditions for Pacific lamprey, hitch and Sacramento sucker by the time the water reaches Stevensons Bridge (upper end of Reach 3) and continuing down into the Yolo Bypass. The temperatures in those reaches (Reaches 1, 2, 3, and perhaps the lower portion of 4) are still somewhat within the range of Sacramento pikeminnow, but well within the range of tule perch, blackfish and threespine stickleback. A synthesis of Yates' determination of potentially suitable spawning habitat and this temperature assessment suggest that Pacific lamprey, hitch and Sacramento sucker currently may have suitable spawning habitat only in Reach 5 and some or all of Reach 4, ending at or near Stevensons Bridge. Thus, suitable spawning habitat for Pacific lamprey, hitch, and Sacramento sucker may be less than 0.7 mile, rather than 1.4 miles, based on temperature limitations. This appears to be consistent with the analysis of Dr. Peter Moyle's et al. (2003) analysis of native fish species distributions between 1991 and 2002. It is also likely to be truer of dry years, when

5.4.4 POTENTIAL SPAWNING HABITAT

The locations of reaches potentially suitable for spawning by the four groups of native fishes were identified by Yates (2003) by selecting the segments that met the substrate, depth, and velocity criteria identified in Table 5-4. Those potentially suitable areas were subsequently sampled to determine whether gravel texture was also suitable for spawning. The cumulative length of suitable channel for each fish category is provided in Table 5-6, subtotaled by the type of hydraulic condition. Temperature conditions were not included in the initial determination of potentially suitable spawning habitat, but are considered in the Subsection, 'Temperature,' below, based on limited data.

Overall, there are nearly 9 miles of riffle, run, or pool areas that appear to be potentially suitable for spawning for at least one category of fish. However, the actual length is lower, since the same location may be recorded as suitable for more than one group of fish. The great majority of potentially suitable sites are located in reaches classified as runs (Yates 2003). Most of the gravel along lower Putah Creek is of finer texture than is normally utilized by steelhead, salmon, and lamprey for spawning. This is further supported by the use of a high proportion of the predicted suitable spawning sites for redds by the salmon that migrated up

Putah Creek in fall 2003, and the selection of sub-optimal conditions for several redds, as described in the Subsection, "Fisheries After Water Accord (2000 to present), above. The selection criteria used to identify potentially suitable spawning segments were approximate. However, with additional information or new estimates of spawning requirements, the location of potentially suitable habitat areas can be refined (Yates 2003). Following are Gus Yates' assessments of potentially suitable habitat for each fish group.

Table 5-6
Cumulative Length of Potentially Suitable Spawning Habitat along Lower Putah Creek

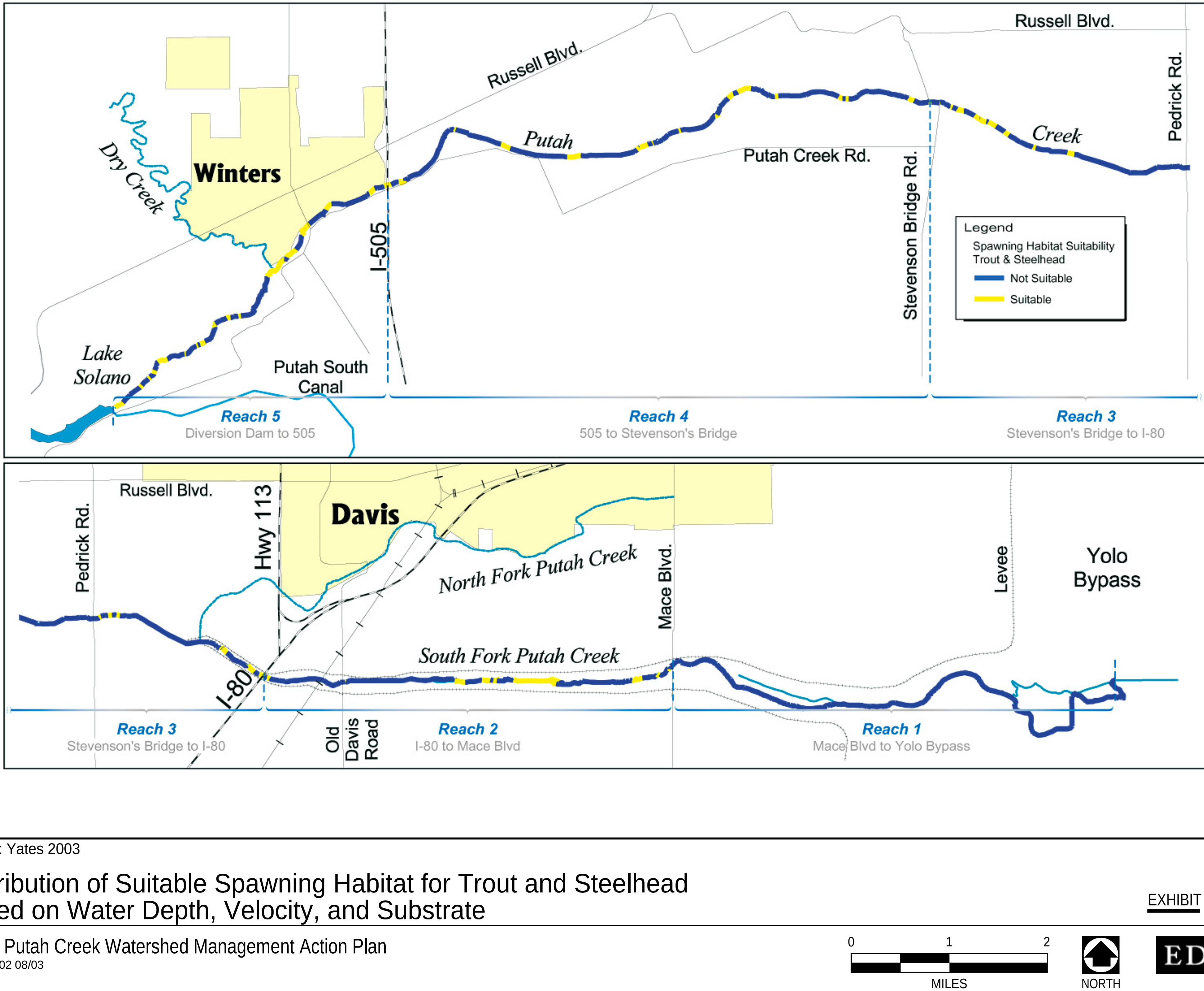
Substrate Type	Miles of Spawning Habitat			
	Pool	Riffle	Run	Total
Chinook salmon	0.00	0.19	1.67	1.86
Rainbow trout/Steelhead	0.24	0.83	2.91	3.98
Pacific lamprey	0.06	0.19	1.42	1.67
Hitch, Sacramento sucker, Sacramento pikeminnow	0.00	0.11	1.31	1.42
Source: Yates 2003				

RAINBOW TROUT AND STEELHEAD

The locations of channel segments that meet the criteria for trout and steelhead are shown in Exhibit 5-16. The criteria are a water depth between 0.4 feet and 5.0 feet, a velocity between 0.6 feet per second (ft/sec) and 4.9 ft/sec and a gravel substrate. Areas with these characteristics total about 4 miles of creek channel. They are distributed as short segments located between the PDD and Mace Boulevard (reaches 2–5), mainly in runs. The total length of potentially suitable spawning reaches for trout and steelhead is more than double the total length for any of the other fish categories because of the broader depth and velocity tolerances for trout and steelhead (Yates 2003).

CHINOOK SALMON

The distribution of potentially suitable spawning habitat for salmon is shown in Exhibit 5-17. The combined length of those segments is 1.86 miles, about half of the total length for trout and steelhead. The depth and velocity ranges for salmon are within the ranges for trout and steelhead, and the gravel texture and thickness are the same, so the suitable segments for salmon are a subset of those for trout and steelhead (Yates 2003). The suitable spawning locations for salmon are also distributed throughout the same reaches as trout and steelhead (Yates 2003). The segments identified as potentially suitable include the location where salmon were seen spawning in 1998, a half-mile downstream of Stevensons Bridge (Yates 2003).

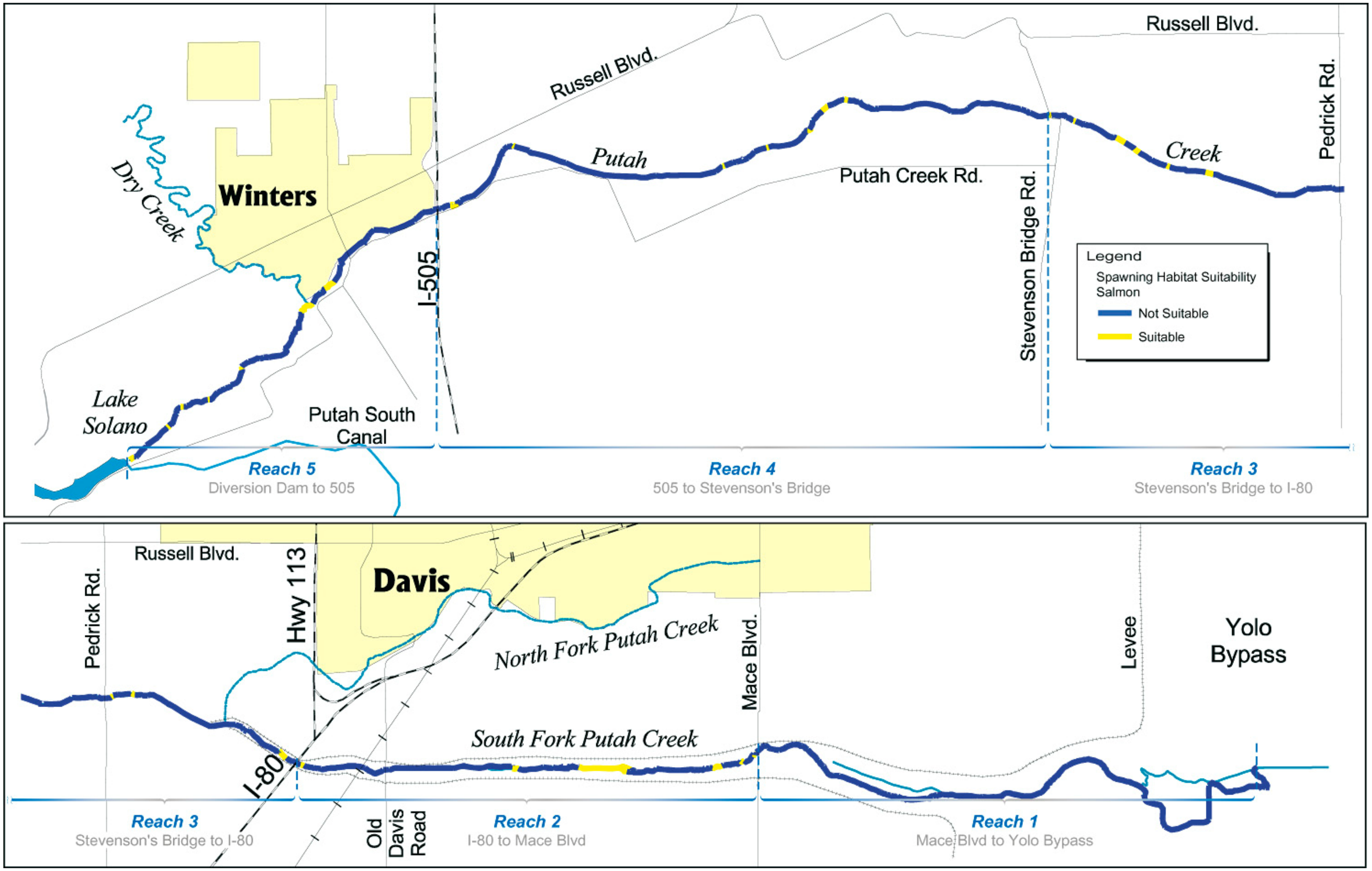


Source: Yates 2003

Distribution of Suitable Spawning Habitat for Trout and Steelhead Based on Water Depth, Velocity, and Substrate

EXHIBIT 5-16

EDAW



Source: Yates 2003

Distribution of Suitable Spawning Habitat for Salmon Based on Water Depth, Velocity, and Substrate

EXHIBIT 5-17

0 1 2
MILES
NORTH

EDAW

Following the return of the first substantial salmon run in decades, in 2003, the use of potential suitable spawning sites could be compared. Exhibit 5-13 shows the location of redds in comparison to the potentially suitable spawning sites. Based on the survey by Moyle and Crain (2003) of lower Putah Creek from the PDD to Old Davis Road, it appears that the salmon used all suitable sites with the right combination of coarse gravel, fast water and depth (Moyle, pers. comm., 2003). All redds were found between the PDD and just downstream of Pedrick Road. No redds were recorded below the North Fork Putah Creek juncture. A total of 19 (48%) out of 40 redds surveyed by Moyle and Crain (2003) were located in areas determined by Yates (2003) to be suitable. An additional 4 (10%) redds were located within 100 feet of sites considered to be suitable. The majority, or 16 of the redds in these areas were located in gravel, while the remaining 7 were in patchy gravel.

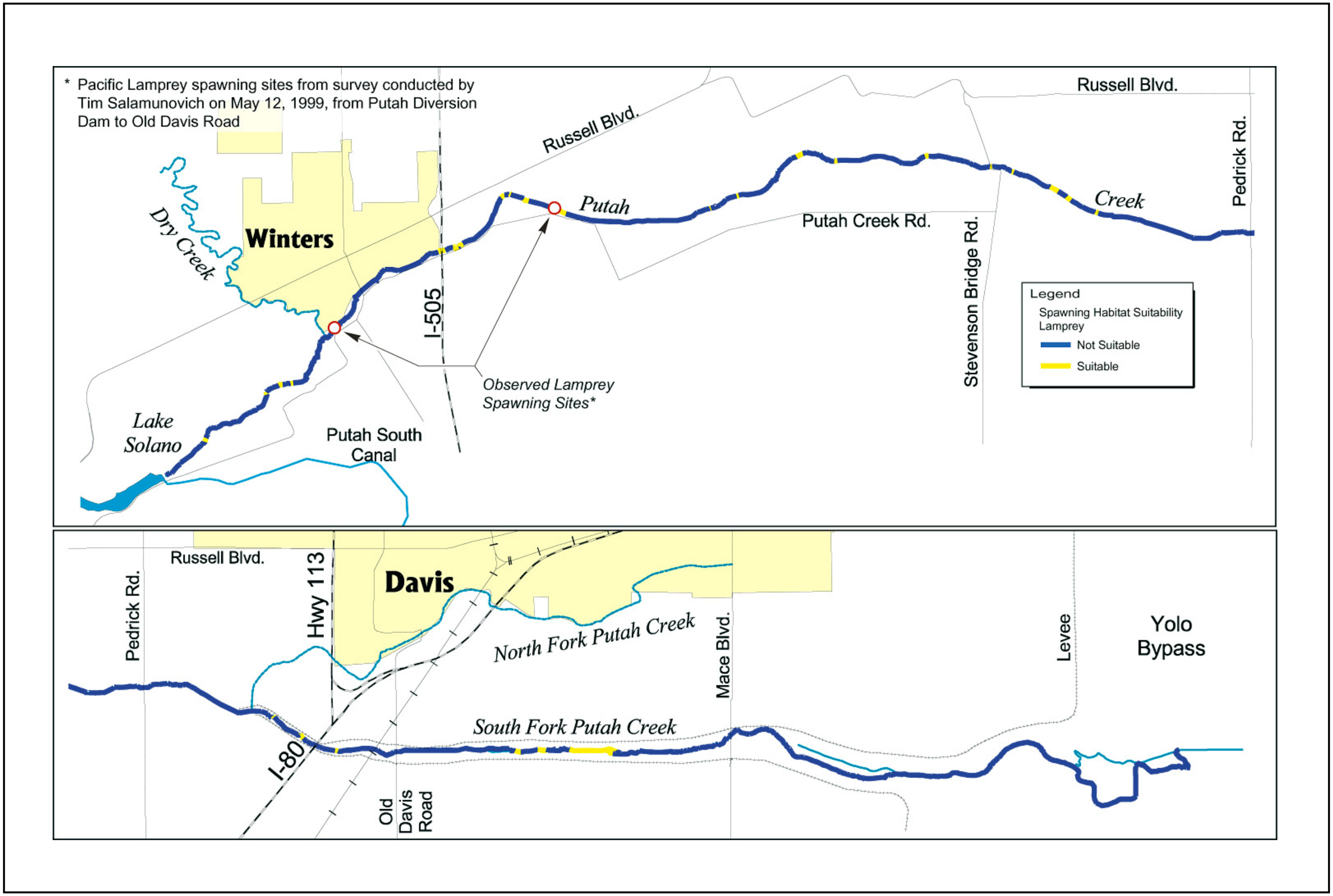
The maximum depth of water at redd sites identified as potentially suitable was 14 to 24 inches and the hydraulic conditions included 8 pools, 1 riffle and 14 runs. The remaining 17 (42%) redds not located in areas determined to be suitable were nonetheless characterized by substrate and hydraulic conditions largely similar to those considered to be potentially suitable. They included 8 redds in gravel, 6 in patchy gravel, 2 in sand and gravel, and only 1 in claypan. The maximum depth of water at redd sites not identified as potentially suitable was 12 to 21 inches and the hydraulic conditions included 5 pools, 7 riffles and 5 runs. Further discussion of the return of fall run chinook salmon in large numbers to lower Putah Creek in 2003 is provided in the subsection, Fisheries After Water Accord (2000 to present).

PACIFIC LAMPREY

Segments of potentially suitable spawning habitat for Pacific lamprey are shown in Exhibit 5-18. The depth and velocity ranges for lamprey are a subset of the ranges for trout and steelhead. Unlike the salmonids, however, lamprey were assumed to be able to utilize patchy gravel substrate, as confirmed by their use of the low road crossing (Exhibit 5-5). The total river miles of potentially suitable lamprey spawning habitat is about 1.7 miles, similar to the total for salmon. Slightly more than half of the individual stream segments suitable for lamprey are also suitable for salmon. The lamprey segments are scattered throughout lower Putah Creek in all reaches from the PDD to Mace Boulevard (Yates 2003). Observations of lamprey spawning in the creek are described in subsections Lower Putah Creek Downstream of PDD and Fisheries Prior to Water Accord (1960s to 2000).

SACRAMENTO PIKEMINNOW, HITCH, AND SACRAMENTO SUCKER

The locations of creek segments potentially suitable for spawning by Sacramento pikeminnow, hitch, and Sacramento sucker are shown in Exhibit 5-19. The criteria for these species are similar to those for lamprey and, therefore, the 1.4 total miles of suitable sites is also similar (Yates 2003).

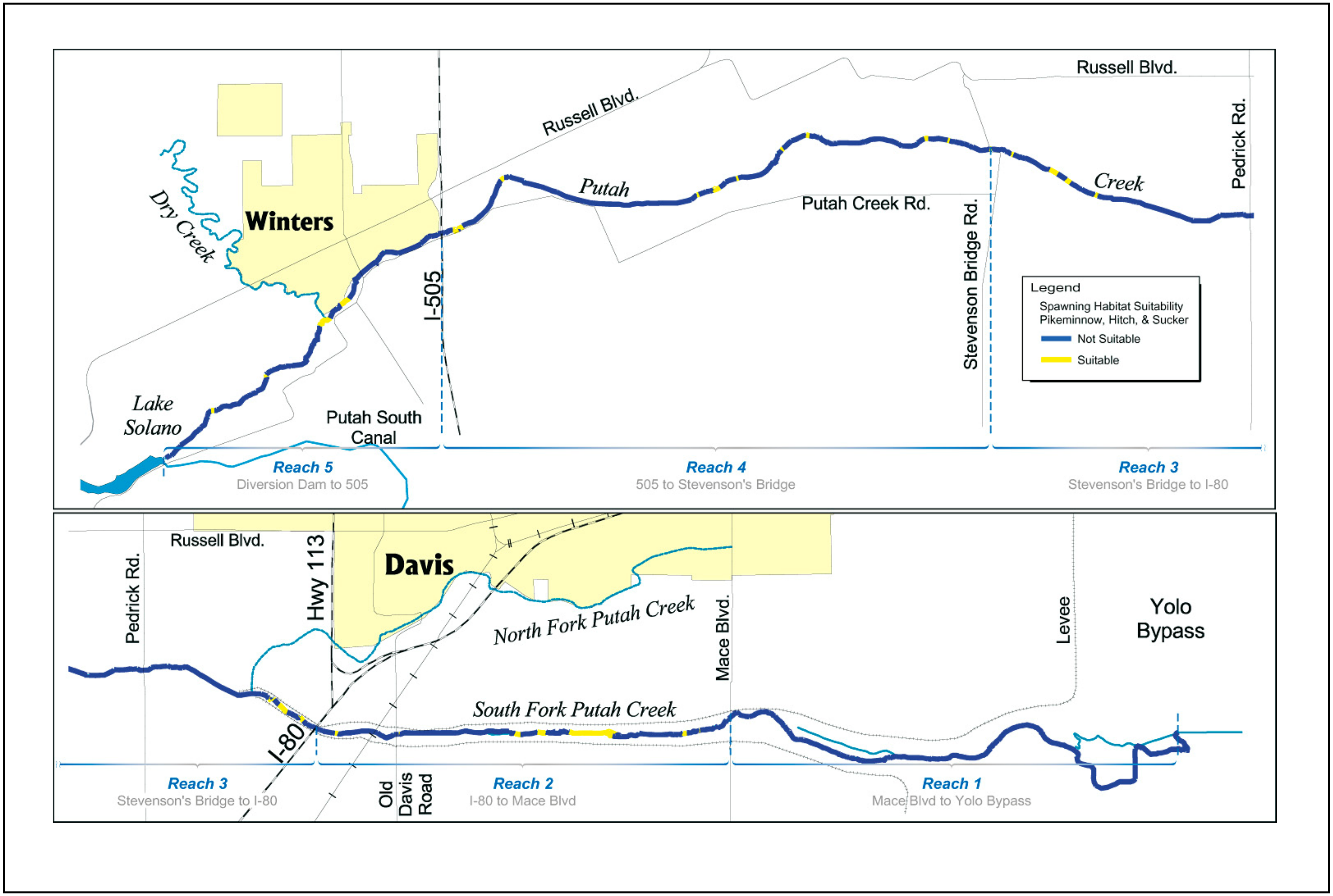


Source: Yates 2003

Distribution of Suitable Spawning Habitat for Lamprey and Observed Spawning Sites

EXHIBIT 5-18

0 1 2
MILES
NORTH
EDAW



Source: Yates 2003

Distribution of Suitable Spawning Habitat for Pikeminnow, Hitch, and Sucker Based on Water Depth, Velocity, and Substrate

EXHIBIT 5-19

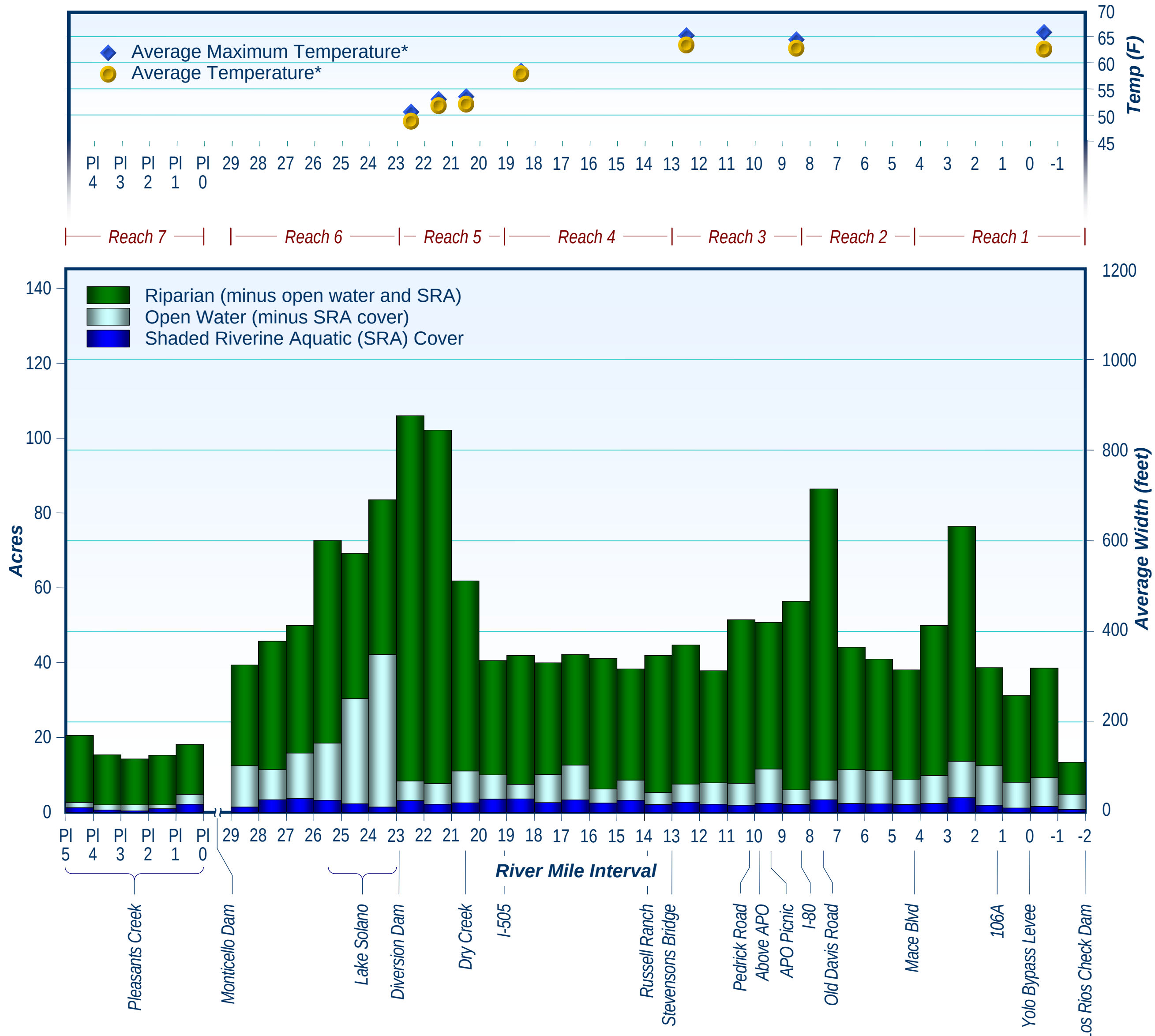
Lower Putah Creek Watershed Management Action Plan

P 1T136.02 08/03

0 1 2
MILES

NORTH

EDAW



* Temperature data are the average maximum temperatures in April and average hourly temperatures recorded in April based on 1997 and 1999-1002 data provided by SCWA.

Source: SCWA 2003, EDAW 2003

Average Size of Habitat Types and Water Temperatures in April* by River Mile

EXHIBIT 5-20

EDAW

smaller releases from the PDD are likely to result in quicker heating of downstream water. In wet years, and likely with Accord flows, the water remains cooler further downstream. Any additional enhancement to improve the channel form, SRA cover, and the riparian corridor are likely to add to this effect.

Based on the fish data (LPCCC 2003), the first 4 miles downstream of the PDD typically have a much higher proportion of Sacramento sucker than areas near Russell Ranch and Stevensons Bridge. The dominance among native species switches from Sacramento sucker in Reach 5 to Sacramento pikeminnow in the lower portion of Reach 4 (Exhibits 5-8 and 9) in non-drought years. In dry years, the shift occurs further upstream (Exhibit 5-11). Sacramento sucker, as with all native fishes, drops off sharply in population size beginning in Reach 3 and continuing downstream. In years of drought prior to the Accord flows, the population drop was much further upstream, within the first 4 miles or less. However, with the Accord flows, native fish appear to be increasing in population size, such that the Sacramento pikeminnow, and to a lesser extent the Sacramento sucker and tule perch, account for a relatively high percentage (over 20%) of total fish abundance (native and introduced) well into Reach 3, before dropping off in population. The Accord releases from PDD could result in the maintenance of cooler water temperatures further downstream then prior to their implementation. However, due to the limited amount of temperature data available, and the short time period since Accord flows have been implemented, additional temperature data and further fish sampling and analyses would need to be conducted to confirm whether the Accord flows are reducing water temperatures and increasing the extent and quantity of suitable spawning habitat for native species in lower Putah Creek.

5.5 SHADED RIVERINE AQUATIC COVER HABITAT ASSESSMENT AND CHANNEL AND RIPARIAN CORRIDOR SIZE ANALYSIS

SRA cover habitat is the interface between riparian vegetation and an adjacent aquatic environment. Both overhead (i.e., riparian trees and shrubs) and instream (i.e., undercut banks, submerged vegetation, roots, low-hanging branches, vegetative debris) SRA cover habitat are important to maintaining suitable habitat for native fish because they regulate water temperature and water quality, provide food and shelter, and can provide native fish with some protection from non-native predatory fish. The width of the creek channel and the extent of the riparian corridor are also important attributes for fisheries, because they influence flow velocity, water depth and water temperature. For instance, a wide open water area may be mostly unshaded and heat up relatively quickly. Since the water does not cool down, this can result in warm water from the wide area all the way downstream, thus affecting the type of fish that can live there. Similarly, a wide, dense multistory riparian corridor can provide insulation against warm air moving across the creek corridor, thus reducing convective heating of the water. In shaded reaches of lower Putah Creek, cool microclimates persist even on hot days (Marovich, pers. comm., 2003).

EDAW evaluated SRA cover habitat along lower Putah Creek using two methods. The first was a qualitative assessment conducted in the field. The second method involved analyzing aerial photographs and estimating shaded aquatic areas versus open (i.e., unshaded) water areas along Putah Creek using Geographic Information Systems (GIS). The riparian corridor width was also assessed. Each of these methods is described below.

The qualitative SRA cover assessment was conducted in summer 2002 concurrently with the vegetation and wildlife habitat assessment described in Chapter 6, "Vegetation and Wildlife." At 75 sampling locations approximately 0.5 mile apart, five habitat attributes that are important components of SRA cover habitat were classified as good, fair, or poor. Based on these results, the overall habitat quality for the wildlife group was rated as optimal, moderate, low, or absent. The habitat attributes for SRA cover habitat included:

< Riparian shrubs and trees that overhang and shade the creek.
< Herbaceous and low-growing plants (e.g., sedges) that overhang and shade the creek.
< Natural banks that support riparian vegetation rather than concrete levees or rip-rap.
< In-stream vegetation and debris such as logs, branches, and leaves.
< Under-cut banks and exposed tree roots that create cover.

The aerial photograph SRA cover, creek channel, and riparian corridor assessment was conducted by using high resolution aerial photographs (flown in 2001) to delineate and calculate areas of open water, shaded water, and riparian corridor using GIS. Because the vegetation often obscured the creek bank, the precise edge of the water was estimated based on areas where the bank was visible. Although this method quantifies the approximate acreage and average width (per river mile) of vegetation overhanging the creek, it does not include an assessment of the quality of the habitat because other components, such as natural banks or in-stream debris were not visible on the photographs. In other words, a large area of SRA cover habitat does not necessarily mean that it is high-quality habitat. This method also did not include an assessment of shading based on the sun's angle to the creek. So, while the method provides a reasonable estimation of the relative differences in total SRA cover habitat between reaches, it is not likely to be an accurate estimate of the actual shaded area over the creek. The riparian corridor generally was delineated as the area extending to farmland and levees. This delineation is described in more detail in the methods subsection in Chapter 6, "Vegetation and Wildlife." The riparian corridor assessment does not take into account the fact that the area includes tall and short vegetation cover or, in some areas, little to no cover.

5.5.1 SRA Cover, Creek Channel, and Riparian Corridor Assessment Results

Exhibit 5-20 shows the total acreage and average width of overhead SRA cover, open water, and riparian corridor, summarized by river mile. Table 5-7 provides a summary of SRA cover and open water habitat type acreages and proportions, by reach. Table 5-8 provides a summary of SRA cover, open water, and riparian corridor dimensions by river mile.

Table 5-7 SRA Cover and Open Water Habitat By Reach			
Reaches	SRA Cover (acres)	Open Water Area (acres)	SRA Cover Percent of Open Water
Reach 1	11.7	57.1	20%
Reach 2	10.2	40.8	25%
Reach 3	11.1	40.4	27%
Reach 4	18.2	52.1	35%
Reach 5	11.3	34.9	32%
Reach 6	16.8	140.2	12%
Putah Creek Total	79.1	365.4	22%
Pleasants Creek (Reach 7)	5.1	13.0	39%
Source: EDAW 2004			

Lower Putah Creek has a total of approximately 79 acres (22%) of SRA cover habitat out of 365 acres of open water habitat in Reaches 1-6, based on the aerial photograph analysis. Most sampling locations along lower Putah Creek were characterized as having moderate SRA cover habitat. In general, the sampling locations are characterized by good to fair amounts of high (e.g., trees and shrubs) and low (e.g., sedges) vegetation that overhang the water, instream vegetative debris (e.g., leaves, branches, logs), and naturally eroding banks with undercuts. Following is a summary of the assessment of SRA cover habitat extent and quality, and the creek channel and riparian corridor extents, by reaches.

REACHES 1, 2, AND 3

Reaches 1, 2, and 3 have a moderate proportion (20–27% by reach) of SRA cover to total water area, and the quality of the SRA cover is considered moderate overall. The creek channel in these reaches varies from a low of about 40 feet wide, on average, in the Yolo Bypass ditches, to an average of about 85 feet wide through most of Reach 2 and about 65 feet wide through most of Reach 3. Also in Reaches 1–3, the riparian corridor ranges from an extremely narrow swath averaging under 100 feet wide along each bank in the Yolo Bypass portion of Reach 1, to moderately wide (i.e., average width of 120–320 feet wide) along each of the upstream banks in Reach 1 and all of Reaches 2 and 3.

REACHES 4 AND 5

Reaches 4 and 5 have the highest percentage (32–35% by reach) of SRA cover along the mainstem of lower Putah Creek. Like Reaches 1, 2, and 3, SRA cover habitat quality in Reaches 4 and 5 is considered moderate overall. The creek channel is moderately wide in those reaches, averaging between approximately 45 and 105 feet wide, and the riparian vegetation is relatively dense adjacent to the channel. The riparian corridor in Reaches 4 and 5 range from an average of 120 to 150 feet wide on each bank, in the downstream stretches, to a higher range of 210–400 feet wide on each bank, on average, in the upper 3 miles of Reach 5, between the PDD and Dry Creek confluence.

Table 5-8 SRA Cover, Open Water, and Riparian Corridor Habitat by River Mile							
River Mile Interval	SRA Cover (acres)	Open Water (acres)	SRA Cover % of Open Water	SRA Cover Avg. Width (ft)	Open Water Avg. Width (ft)	Riparian Corridor[1] (minus water, SRA) (acres)	Riparian Corridor[1] (minus water, SRA) Avg. Width (ft)
-2 to -1	0.94	5.8	16%	6	34	10.24	71
-1 to 0	1.40	8.2	17%	13	63	26.12	124
0 to 1	0.93	6.5	14%	9	57	18.77	192
1 to 2	1.93	12.5	15%	16	87	26.43	217
2 to 3	3.90	13.7	29%	32	81	62.89	519
3 to 4	2.37	9.8	24%	20	62	40.02	331
4 to 5	2.16	9.1	24%	17	56	30.09	241
5 to 6	2.30	11.6	20%	18	74	31.17	246
6 to 7	2.39	11.6	21%	19	75	33.28	270
7 to 8	3.35	8.6	39%	28	44	78.12	643
8 to 9	2.24	6.3	36%	18	32	53.01	417
9 to 10	2.41	11.7	21%	20	76	39.36	323
10 to 11	1.93	7.8	25%	16	48	44.10	362
11 to 12	2.19	8.0	28%	18	47	30.20	248
12 to 13	2.74	7.6	36%	22	40	37.69	308
13 to 14	2.07	5.3	39%	17	27	36.92	303
14 to 15	3.30	8.8	38%	27	44	30.33	245
15 to 16	2.46	6.4	39%	20	32	35.35	288
16 to 17	3.38	12.9	26%	27	77	30.07	244
17 to 18	2.62	10.2	26%	21	62	30.24	247
18 to 19	3.65	7.6	48%	30	32	34.89	285
19 to 20	3.56	10.1	35%	29	54	30.73	252
20 to 21	2.78	12.2	23%	21	70	55.86	420
21 to 22	2.26	7.9	29%	18	45	97.24	781
22 to 23	3.24	8.6	38%	26	43	99.89	807
23 to 24	1.43	42.8	3%	12	337	42.07	342
24 to 25	2.34	30.8	8%	19	232	39.39	321
25 to 26	3.41	19.4	18%	27	126	57.00	448
26 to 27	3.74	16.1	23%	30	101	34.70	282
27 to 28	3.38	11.6	29%	28	67	34.73	283
28 to 29	1.48	13.0	11%	12	91	28.02	222
Putah Creek Total	**78.6**	**365.6**	**22%**	**20**	**75**	**1,283**	**334**
Pl 0 to Pl1	2.1	4.6	46%	18	22	13	110
Pl 1 to Pl2	0.9	2.0	47%	8	9	13	110
Pl 2 to Pl3	0.4	2.0	21%	3	13	12	102
Pl 3 to Pl4	0.6	2.0	31%	5	11	14	111
Pl 4 to Pl5	1.0	2.1	48%	10	11	15	148
Pleasants Creek Total	**5.1**	**12.7**	**40%**	**9**	**13**	**67**	**115**

[1]Riparian corridor values do not include open water or SRA habitat acreage/widths.

REACH 6

Reach 6 has the lowest percentage of SRA cover (12% of total water area) in lower Putah Creek. This is primarily due to the large expanse of open water in Lake Solano. In addition, Lake Solano has the most areas of low quality SRA cover habitat in lower Putah Creek. In general, most of the habitat attributes described above were classified as fair or poor around Lake Solano.

REACH 7, PLEASANT CREEK

SRA cover in Pleasants Creek (Reach 7) is characterized as contributing 39% to the total water area. However, from the qualitative field assessment, it is clear that most of Pleasants Creek dries up in summer; therefore the SRA cover estimate for Pleasants Creek is unlikely to be valid during summer months. SRA cover habitat was characterized as poor, primarily since aquatic habitat was frequently absent during the time of the survey in late summer. However, because these areas are upstream of the PDD, and anadromous fish are currently unable to pass the Dam, SRA cover habitat in that area may be less important. The riparian corridor along Pleasants Creek is generally extremely narrow, averaging only about 51 to 75 feet wide along each bank.

5.6 FISH PASSAGE ISSUES

Salmon, lamprey and steelhead migrating up lower Putah Creek to spawn, and later returning to sea have to make it past obstacles. Two structures, the PDD and Monticello Dam, completely block migration into historic spawning and rearing areas in the interdam reach and as far upstream as the Berryessa Valley. To migrate into Putah Creek, anadromous fish return through San Francisco Bay, north to San Pablo Bay, through the Carquinez Strait into Suisun Bay and up the Sacramento River into Cache Slough just upstream from Rio Vista. From Cache Slough they swim through Prospect Slough and into the manmade East Toe Drain of the Yolo Bypass (Exhibits 1-1, 1-2, and 1-3). After swimming up the East Toe Drain they reach the Lisbon Weir—a mound of rock that captures water at low tide. At high tide both water and fish pass over the rocks. After about another 1½ mile, the fish swim into the treeless, excavated Yolo Bypass ditch where Putah Creek connects to the East Toe Drain. After swimming 2 miles across the Bypass channel the fish reach the first major obstacle, the Los Rios Check Dam, a 12-foot-high, 30-foot-long concrete box that serves as a seasonal check dam in the Yolo Bypass to create a head of water for irrigation pumping and to flood the Yolo Basin Wildlife Area. The Los Rios Check Dam is currently being managed to optimize the migration of fall run chinook into lower Putah Creek by removing boards in fall in conjunction with pulse flow releases from the PDD, as discussed in the subsection, Putah Creek Water Accord, above (Exhibit 5-21).

(A) Los Rios Check Dam waterfall (approx 7 ft. tall) across boards, (B) boards are removed at Los Rios Check Dam in fall timed with pulse releases from the Putah Diversion Dam to enable passage of chinook salmon and other anadromous fish, (C) Los Rios Check Dam following removal of boards, (D) collapsed Winters percolation dam looking upstream (west), (E) Putah Diversion Dam, (F) beaver dam (January 2004) downstream of Mace Blvd. Photo credits: Dave Feliz (Los Rios Check Dam photos); US Bureau of Reclamation (Putah Diversion Dam); UC Davis Department of Wildlife, Fish, and Conservation Biology (beaver dam).

Source: Dave Feliz (CDFG) 2003; UC Davis 2004; USBR 2004; EDAW 2003

Putah Creek Fish Passage Issues

EXHIBIT 5-21

Swimming upstream past the check dam, fish may reach one to several beaver dams over the next 20 miles of lower Putah Creek. The beaver dams are typically broken up and washed downstream during high flow events, but during dry and moderate rainfall periods, the dams can persist for years. If flows are insufficient to overtop or bypass the dams during migration periods, the fish may have difficulty in passing over or around them. Increased flow releases (e.g., from storm events) from the PDD during spawning have assisted the fish in passing the beaver dams often by flooding side channels faster than beavers can plug them. Just 3 miles upstream of the Los Rios Check Dam, fish pass the location of the Road 106A seasonal earthen road crossing. The crossing is installed annually in spring for farm operations and the road and culverts are removed in fall, which allows for fish passage upstream. During late season rainstorms, Road 106A can fail, as occurred in the spring of 2003. (See Exhibit 4-3b in Chapter 4, "Geomorphology, Hydrology, and Water Quality."). The culverts underlying Road 106A are considered a possible impediment to fish passage (DWR 2003).

After swimming upstream about 21 miles from the Los Rios Check Dam, the migrating fish encounter the percolation dam in Winters (Exhibit 5-21). The 100-foot-wide concrete structure was built in 1936 and collapsed during a flood in 1951. (See the subsection, Hydrology Prior to the Solano Project, in Chapter 4 for more details.) The Winters percolation dam continues to partly obstruct passage, especially during low flows and when debris clogs passageways through the dam. Passing the percolation dam, the fish swim another 4 miles before reaching the PDD, a gated concrete weir 29 feet tall and 910 feet wide (Exhibit 5-21).

The PDD currently prevents further passage to the interdam reach. If passage is someday achieved by a bypass channel or other means, the fish would have access to historic spawning areas in the interdam reach and could swim another 6 miles upstream before reaching Monticello Dam, a concrete dam 304 feet high and over 1,000 feet wide that prevents further migration from the interdam reach to the historic Berryessa Valley, now filled by Lake Berryessa, and the upper Putah Creek watershed.

6

Vegetation and Wildlife

6 VEGETATION AND WILDLIFE

This chapter provides an assessment of the existing plant communities and wildlife habitats present along the lower Putah Creek and Pleasants Creek riparian corridors. It presents a qualitative evaluation of habitat quality for groups of wildlife species and discusses the importance of riparian habitat to wildlife. For this chapter, habitat is defined as the native environment of an animal or plant, including attributes that provide shelter, food, nesting substrates, or other important elements for plants or animals to grow, survive, and reproduce. The riparian corridor is defined as the area in which typical stream-dependent vegetation (e.g., willows, Fremont cottonwood, and valley oak) grow or can grow, because of the presence of surface water or shallow groundwater. Riparian habitat is one of the most important habitat types for wildlife species because of its rich, complex mixture of vegetation, water, food, and shelter. In California, where hillsides and grasslands are typically dry in summer, riparian habitat is especially important to animals and plants dependent on the availability of summer water. Over the past 200 years, hundreds of thousands of acres of riparian forest have been cleared for development and agriculture. As a result, the existing riparian forest habitat in the state represents approximately 5–10 percent of the total riparian acreage estimated to occur two centuries ago (Barbour et al. 1993, Hunter et al. 1999, RHJV 2000).

This chapter further assesses the suitability of riparian habitats to support sensitive biological resources; analyzes the biological significance of the area in view of federal, state, and local laws and policies; and describes measures to protect sensitive resources.

6.1 METHODS

A survey of vegetation and wildlife habitats was conducted during summer 2002. A total of 75 sampling locations was established at approximately 0.5 mile intervals along lower Putah Creek, from Monticello Dam to the Los Rios Check Dam on the west side of the Yolo Bypass, and along Pleasants Creek, from Lake Solano to approximately 4 miles upstream. The sampling locations were visually assessed from public roads or from canoes when road access was unavailable. The area encompassed by each sampling location varied based on access and visibility, but generally included a zone approximately 300–500 feet long. An example of the sampling datasheet is provided in Appendix B.

At each sampling location, plant communities were classified and their percent cover of the total visible area was estimated. The approximate length of area visible from the sampling location and the ranges of channel width and riparian corridor were estimated in the field using aerial photographs printed at a scale of 1:1,200 (i.e., 1 inch=100 feet). Vegetation structure and species composition data were taken at each sampling location, including the dominant species in different canopy layers. Canopy layers included the herb (ground) layer, shrub (under 15 feet tall), subcanopy (smaller trees not reaching uppermost canopy), and the upper canopy (large trees). However, comprehensive vegetation mapping was not conducted for the entire riparian corridor of lower Putah Creek and Pleasants Creek. A vegetation map of lower Putah Creek was produced as part of the Sacramento River Riparian Mapping Project by the California State University, Chico Geographical Information Center (GIC 2000) and is included in a separate map volume. In some locations, the vegetation types on the GIC map differ from those determined during 2002 surveys because of the time of data collection, as well as differing vegetation classifications, mapping methodologies, and scales of mapping.

Existing vegetation structure and other habitat attributes provided the basis for classifying habitat quality at each sampling location for wildlife groups that included: tree-nesting raptors, other nesting birds (ground/low, shrub, tree, and cavity nesters), and semi-aquatic reptiles (i.e., pond turtles). These wildlife groups were selected because they represent a range of wildlife species with habitat requirements that could be generalized and efficiently measured. The quality of SRA habitat and the connectivity of corridors for animal movement were also evaluated. The SRA cover assessment is discussed in more detail in Chapter 5, "Fisheries."

To classify habitat quality, a checklist of three to five important habitat attributes was developed for each group of wildlife species with sufficiently similar habitat requirements. The value of each habitat attribute was rated as good, fair, or poor. The overall habitat quality for the wildlife group was rated as optimal, moderate, low, or absent. In general, *optimal* habitat included habitat with all necessary habitat attributes present and classified as good. *Moderate*-quality habitat included two or three attributes classified as good, with the remaining attributes classified as fair. *Low*-quality habitat included one attribute classified as good, or all attributes classified as fair. If all attributes were classified as poor, then habitat was considered *absent*. The habitat attributes for each group are described below.

6.1.1 RAPTORS

Raptors that nest adjacent to Putah Creek include, but are not limited to, white-tailed kite, red-shouldered hawk, red-tailed hawk, Swainson's hawk, and great-horned owl. These raptors have similar habitat requirements in that they build platform nests in trees. Other raptors that are known to occur along Putah Creek, such as ground-nesting northern harriers or cavity-nesting American kestrels, have more specialized habitat requirements, and are not included in this group for purposes of the habitat assessment.

Habitat Attributes:

- Tall/mature trees for nests. For example, valley oak, cottonwood, willow, sycamore, and walnut are preferred trees for Swainson's hawk. *Eucalyptus* are also commonly used by raptors.
- Open fields or pastures for foraging adjacent to nesting habitat. Alfalfa, fallow fields, beet, tomato, other low-growing crops, and pastures are some of the preferred foraging habitats for Swainson's hawk.
- Low amount of disturbance in the area.

6.1.2 OTHER NESTING BIRDS

Nesting non-raptorial birds are divided into the following four categories based on their typical nest position:

< Ground/low-nesters – These include species such as song sparrow, lazuli bunting, spotted towhee, and California towhee. They typically build nests 0 to 4 feet above ground.

< Shrub-nesters – These include species such as bushtit and black-headed grosbeak. They typically build nests 4–10 feet above ground.

< Tree nesters – These include species such as western wood-pewee, yellow-billed magpie, and Bullock's oriole. They typically build nests 10 feet or more above ground.

< Cavity-nesters – These include species such as western bluebird, ash-throated flycatcher, and tree swallow. They use cavities for nesting at various heights depending on availability.

Nest position is one of many characteristics that can be used to classify birds into similar groups. Other classification methods include ones based on taxonomy (e.g., warblers), land cover type (e.g., birds associated with riparian woodland), or foraging guild (e.g., seed eaters). Nest position was selected as the classification method for this study cause it allows for a habitat-based analysis that is more refined than using land cover type, and is measured easily and rapidly.

The first three attributes listed below were evaluated for all four groups of land birds collectively. The fourth attribute, which refers to nest substrate availability, was evaluated for each group separately.

Habitat Attributes:

< Complex structure (e.g., presence of herbaceous, shrub, and canopy layers) and high plant diversity.

< Wide riparian corridor.

< Low apparent density of predators, disturbance, or attractants for predators. Considerations might include cats near residential areas, or trash piles and picnic areas which may attract rats, raccoons, or other predators.

< Suitable substrate for nesting (e.g., vegetation near the nest position for concealment, snags, or trees with existing or potential nesting cavities).

6.1.3 WESTERN POND TURTLE

One of the most common native species of reptiles to occur in the lower Putah Creek drainage is the western pond turtle (*Emys marmorata*). Although western pond turtles are relatively common in Putah Creek, western pond turtle populations are declining throughout their range. Western pond turtle is considered a federal and California species of special concern because of habitat loss and alteration, loss of breeding areas and low population recruitment, and increased predation by introduced aquatic species (Jennings and Hayes 1994). By assessing habitat quality for western pond turtle in Putah Creek, more insight into the restoration needs can be obtained.

Habitat Attributes:

< Slack or slow moving water.

< Aerial basking areas, such as logs, rocks, and exposed bank.

< Dense submergent vegetation (e.g., pondweed, ditch grass) for basking and feeding; and/or short emergent vegetation for hatchlings.

< Upland nesting sites (up to 1,300 feet from aquatic habitat) with high clay or silt fraction substrate on an unshaded, often south-facing slope of usually less than 25% gradient.

6.1.4 SHADED RIVERINE AQUATIC COVER HABITAT

SRA habitat is the interface of riparian vegetation and aquatic habitat. Overhead SRA cover, such as riparian trees and shrubs, provides shade over aquatic areas, maintains cool water temperatures, and deposits fallen leaves, branches, and insects into the nutrient cycle of the aquatic system. Instream SRA cover, such as undercut banks, vegetation, roots, low-hanging branches, and vegetative debris, provides a variety of micro-habitats characterized by various flows, depths, cover, and food production. Instream cover also provides a food source, shelter, and spawning substrate for a variety of fish and other aquatic organisms.

Habitat Attributes:

< Riparian shrubs and trees that overhang and shade the creek.
< Herbaceous and low-growing plants (e.g., sedges) that overhang and shade the creek.
< Natural banks that support riparian vegetation rather than concrete levees or rip-rap.
< Instream vegetation and debris such as logs, branches, and leaves.
< Under-cut banks and exposed tree roots that create cover.

6.1.5 WILDLIFE MOVEMENT CORRIDOR

A wildlife movement corridor describes a linear habitat whose primary wildlife function is to connect two or more significant habitat areas. The following attributes facilitate movement for a variety of wildlife species, including large and mid-sized mammals.

Habitat Attributes:

< Vegetative cover for concealment.

- Connectivity. Areas of suitable habitat should be connected without major (greater than 150 feet) gaps in vegetation or obstacles to travel along the corridor.
- Low amount of disturbance in the area.

6.2 HISTORICAL CONDITIONS

Historically, the complex vegetation mosaic created by dynamic, meandering river systems in the Central Valley and surrounding foothills provided resources necessary to support an abundance of resident and migrant wildlife species. This dynamic system created a variety of habitats, including oxbow lake edges, openings and gravel bars, shrubby early-successional vegetation, and mature forest stands. Riparian forests were structurally and floristically diverse, characterized by species such as box elder (*Acer negundo*), Oregon ash (*Fraxinus latifolia*), white alder (*Alnus rhombifolia*), Goodding's and red willow (*Salix gooddingii*, *S. laevigata*), button willow (*Cephalanthus occidentalis*), mulefat (*Baccharis salicifolia*), California nettle (*Urtica dioica*), wild grape (*Vitis californica*), California blackberry (*Rubus ursinus*), Fremont cottonwood (*Populus fremontii*), valley oak (*Quercus lobata*), and California sycamore (*Platanus racemosa*) (Jones & Stokes Associates 1992, Sutter and Dawson 1986). Adjacent uplands were irregularly flooded and supported extensive valley oak woodlands (Russell and Coil 1940).

Prior to settlement of the area through land grants, the vegetation along Putah Creek consisted of a wide riparian forest that extended from the Coast Ranges to the Putah Creek sinks (HortScience 1997). Estimates of the area of riparian vegetation that existed along lower Putah Creek between Winters and the Putah Creek sinks prior to development range from 22,000 to 65,000 acres (Katibah 1984, Kuchler 1977). Calculations using the lower of these estimates suggest that the historical riparian corridor averaged 1.5 miles wide between Lake Solano and the Yolo Bypass (USFWS 1993).

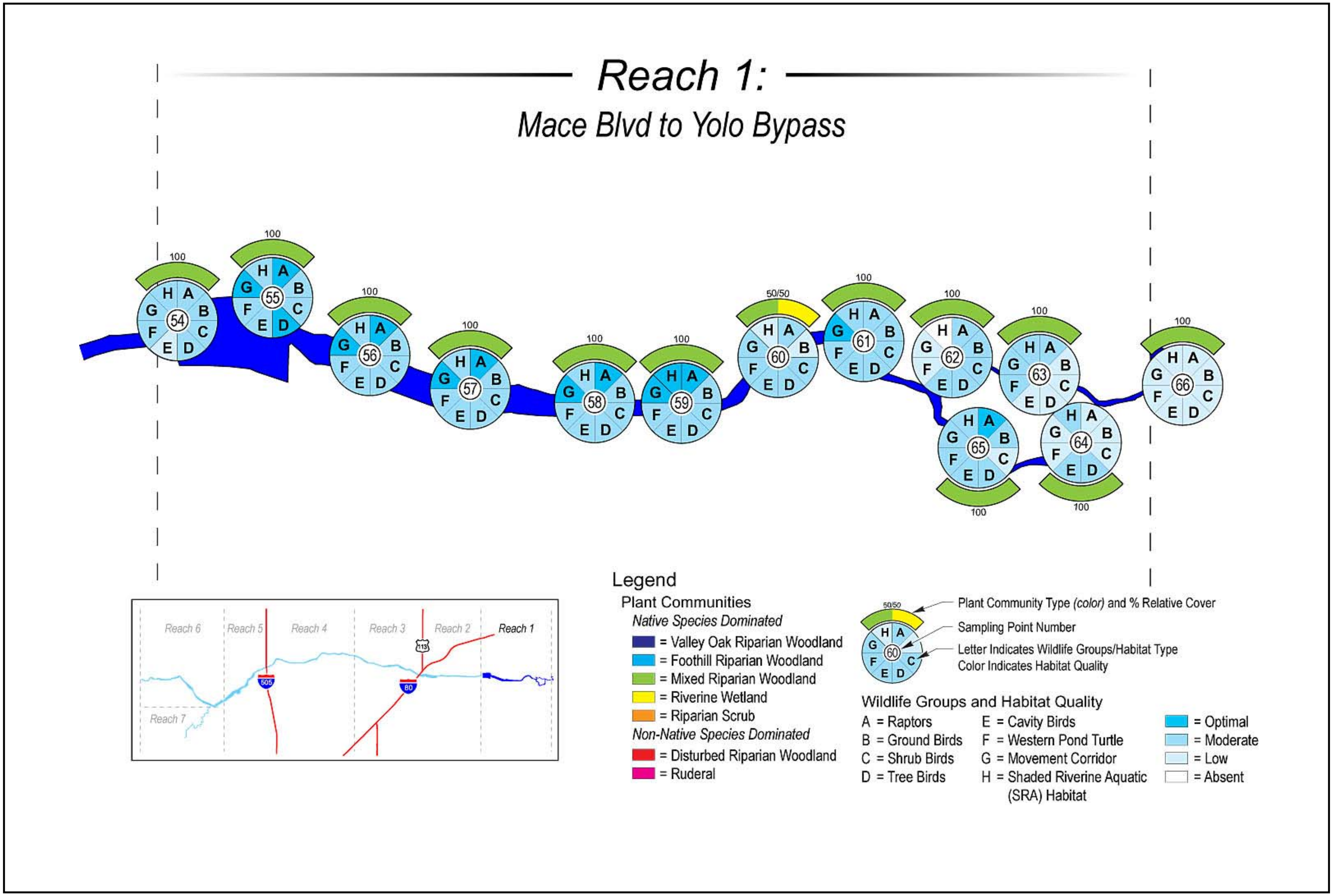
Despite the importance of riparian and wetland habitats, California has lost approximately 90–95% of these habitats over the past 150 years due to reservoir construction, levee and channelization projects, livestock grazing, timber harvest, water pollution, introduction of nonnative invasive plant species, gravel and gold mining, and clearing for agricultural, residential, and industrial uses (Barbour et al. 1993, RHJV 2000). Similarly, Putah Creek has experienced several large-scale changes which have affected natural resources over the last 100 years (HortScience 1997). The riparian vegetation along much of Putah Creek was cleared in the late 1800s as settlements were established and large tracts of land were converted to agricultural uses. In addition, the south fork of Putah Creek was constructed in the late 1800s and completed in the 1940s (USFWS 1993, Larkey 1969). By the 1940s, most of the bank-to-bank riparian vegetation was removed from Winters to the Yolo Bypass (HortScience 1997). Vegetation clearing by the USACE continued into the 1970s. Although trees and other riparian vegetation have re-grown along the creek and are fairly mature in some areas, the riparian corridor is constrained by adjacent land uses, including agriculture, residential and urban development, and roadways. Continuing periodic stream maintenance activities for fire suppression or flood protection also affect riparian woodland structure, SRA habitat, and plant and wildlife species composition.

Presently, we estimate that approximately 2,000 acres of riparian habitat remains along Putah Creek, with a riparian corridor width of 71 to 807 feet. A discussion of the historical changes along lower Putah Creek and Pleasants Creek is provided in Chapter 2, "Cultural Resources." A discussion of the extent of different existing land use types along lower Putah Creek and Pleasants Creek, including the riparian corridor, is provided in Chapter 3, "Land Ownership, Land Uses, and Resource Management Programs." Exhibit 3-2 shows the extent of the current lower Putah Creek and Pleasants Creek riparian corridors relative to other land uses in Solano and Yolo counties.

6.3 EXISTING PLANT COMMUNITIES

This section describes the plant communities observed during surveys conducted in the lower Putah Creek and Pleasants Creek riparian corridor in 2002. Appendix D contains a list of plants observed or known to occur in the lower Putah Creek riparian corridor. The plant communities are characterized by dominant plant species, as well as structural characteristics (e.g., mature trees versus shrubs). Plant communities are typically dependent on a range of conditions (e.g., soil moisture during the growing season, flood frequency, and soil type) that support the plants in those communities. The plant communities described in this section are generally consistent with those described by Holland (1986). It is important to note that plant communities are dynamic, changing in species composition and structural characteristics over time as a result of perturbations such as fires, floods, disease, human activities (e.g., habitat conversion, stream maintenance, and species introductions), and over a longer timeframe, climate change. As a result of varying conditions and perturbations, plant communities intergrade with one another in the landscape. The degree and manner in which they change or remain static, and the degree to which the landscape is homogeneous (i.e., single community) or heterogeneous (i.e., many communities) affects both the type and abundance of wildlife that use the riparian corridor.

The lower Putah Creek riparian corridor is characterized by a mixture of plant communities, including mixed riparian forest, valley oak riparian forest, foothill riparian woodland, riparian scrub, riverine wetland, open water, disturbed riparian woodland, and ruderal (i.e., disturbed or dominated by herbaceous weeds) areas. Agricultural land and developed areas are the dominant land cover types adjacent to the riparian corridor. The dominant native community types throughout the watershed are mixed riparian forest and valley oak riparian forest, representing approximately 60% and 12% of the area surveyed at the 75 sampling locations in the riparian corridor, respectively. About 15% of the area surveyed at the sampling locations consisted of disturbed riparian woodland. Exhibits 6-1a through 6-1g show the relative cover of the plant communities at each sampling location.



Source: EDAW 2004

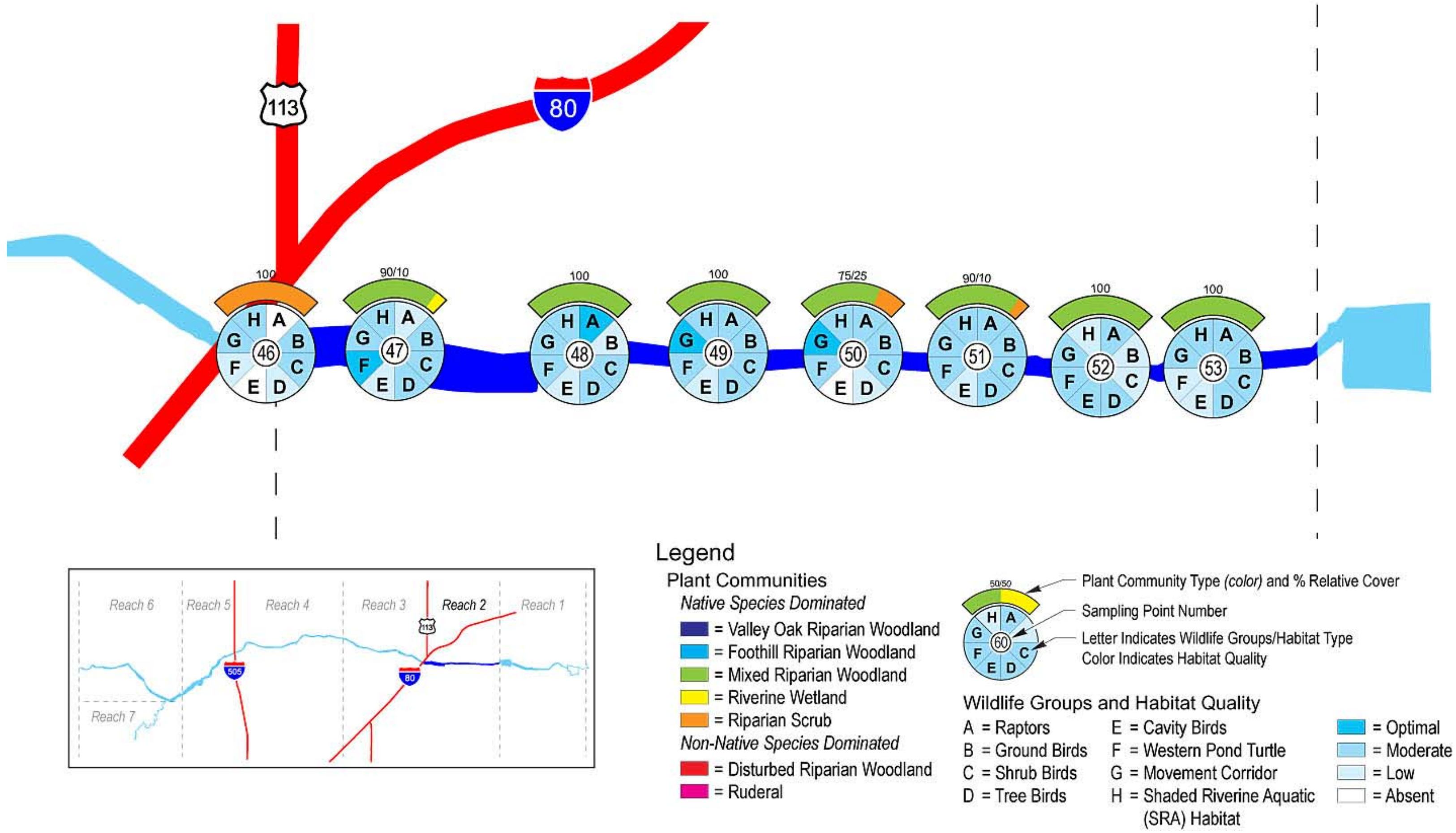
Plant Communities and Wildlife Habitat Quality

EXHIBIT 6-1a

EDAW

Reach 2:

Interstate 80 to Mace Blvd



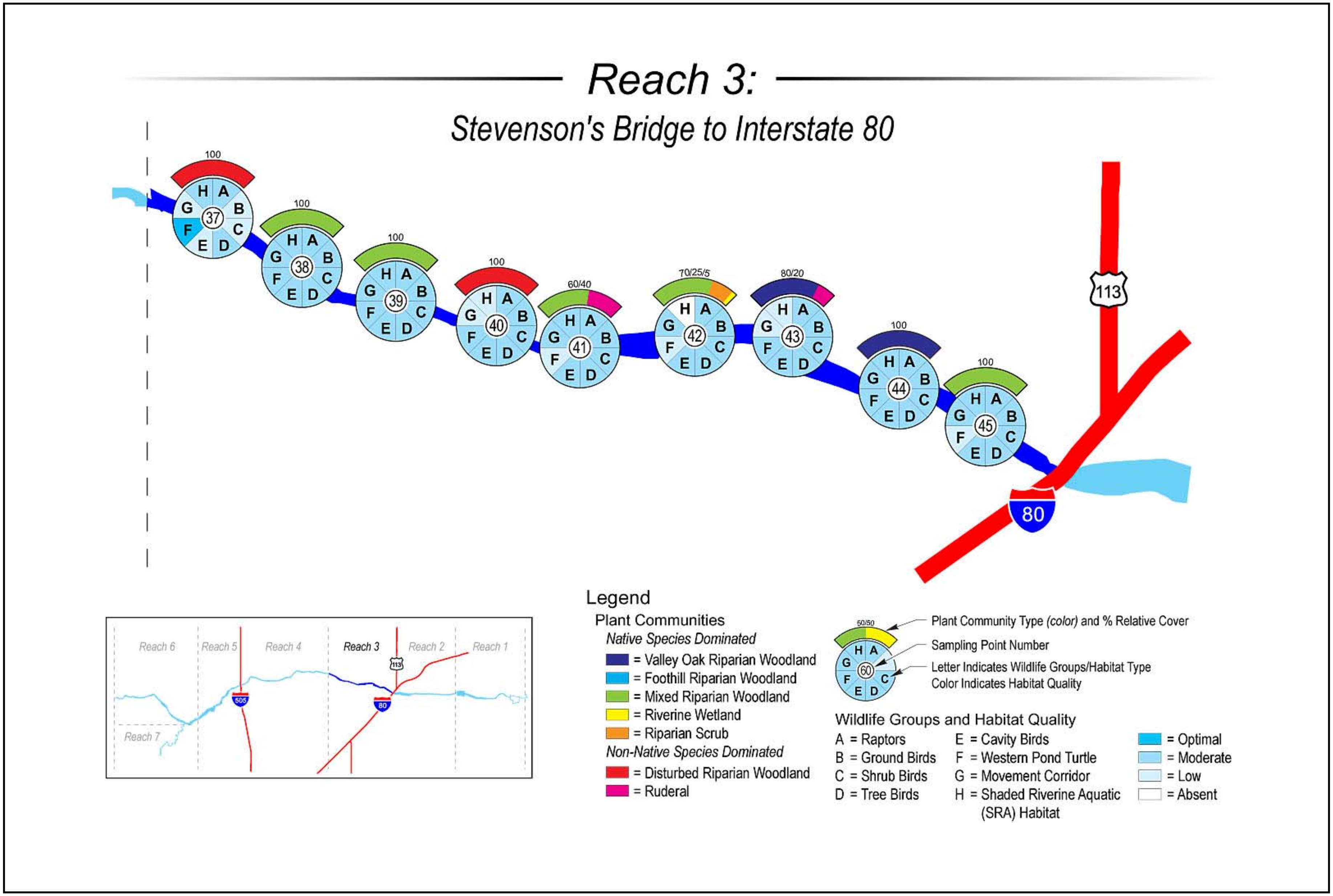
Source: EDAW 2004

Plant Communities and Wildlife Habitat Quality

EXHIBIT 6-1b

Lower Putah Creek Watershed Management Action Plan
P 1T136.02 08/03

EDAW



Source: EDAW 2004

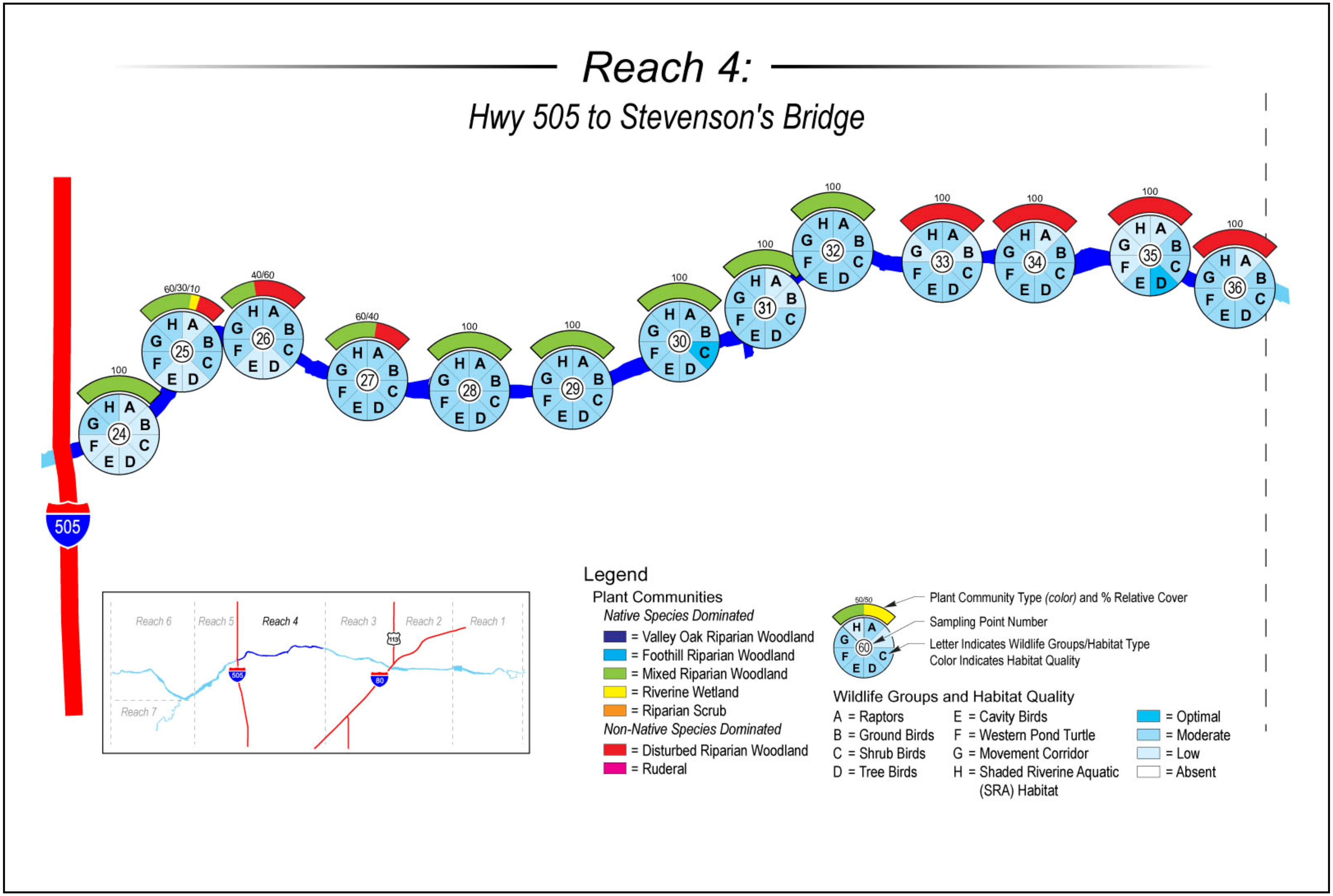
Plant Communities and Wildlife Habitat Quality

EXHIBIT 6-1c

Lower Putah Creek Watershed Management Action Plan

P 1T136.02 08/03

EDAW



Source: EDAW 2004

Plant Communities and Wildlife Habitat Quality

EXHIBIT 6-1d

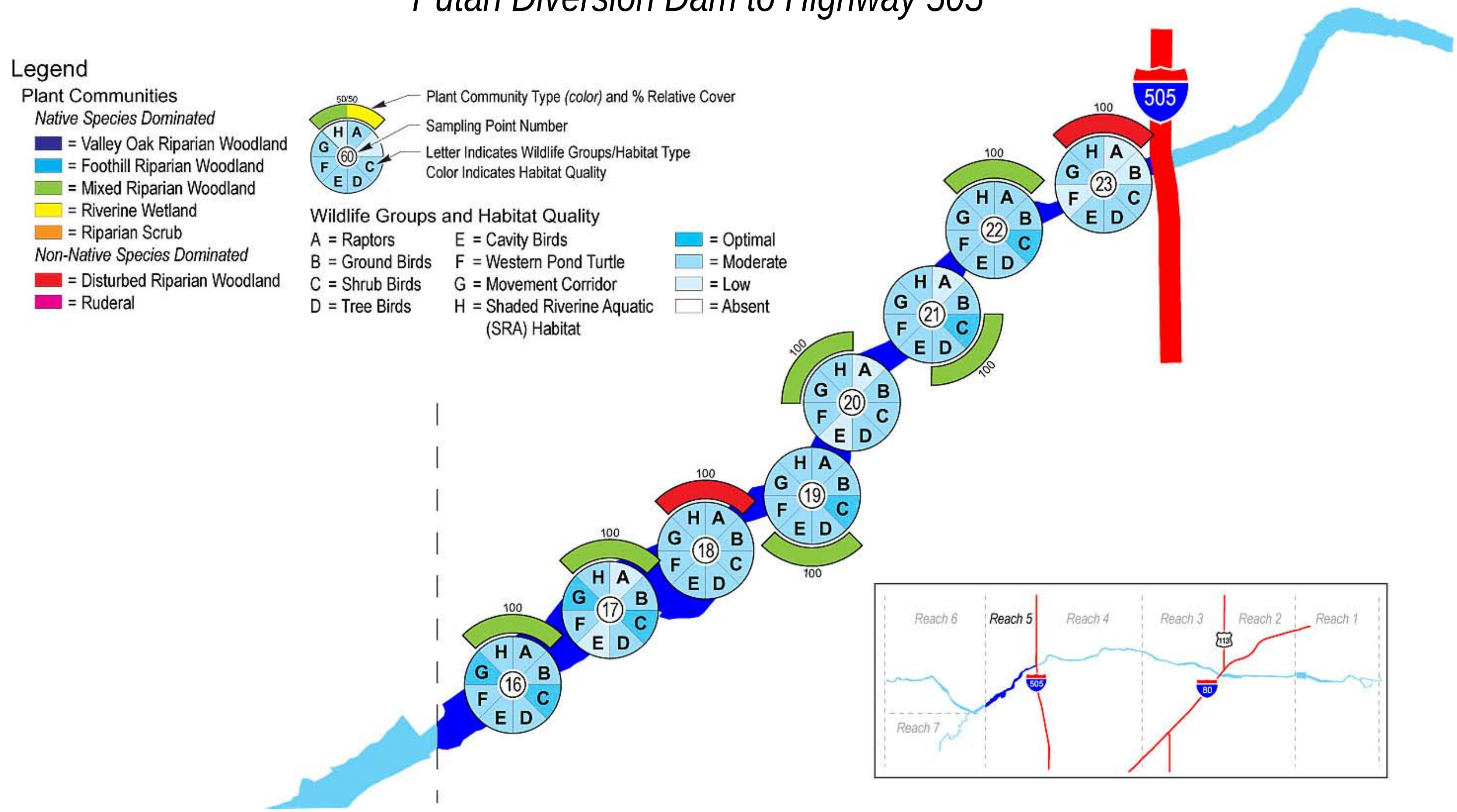
Lower Putah Creek Watershed Management Action Plan

P 1T136.02 08/03

EDAW

Reach 5:

Putah Diversion Dam to Highway 505



Source: EDAW 2004

Plant Communities and Wildlife Habitat Quality

EXHIBIT 6-1e

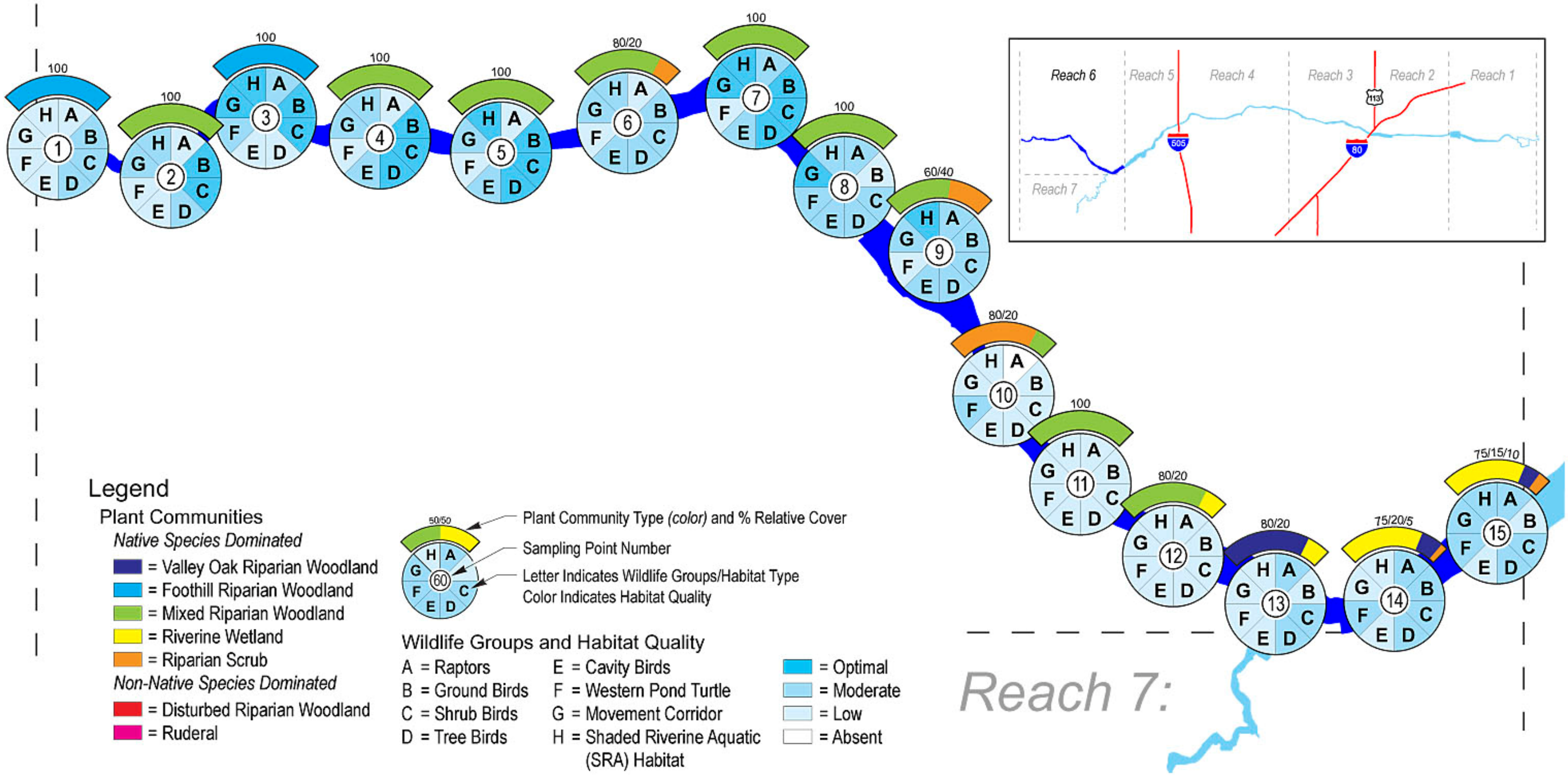
Lower Putah Creek Watershed Management Action Plan

P 1T136.02 08/03

EDAW

Reach 6:

Monticello Dam to Putah Diversion Dam



Source: EDAW 2004

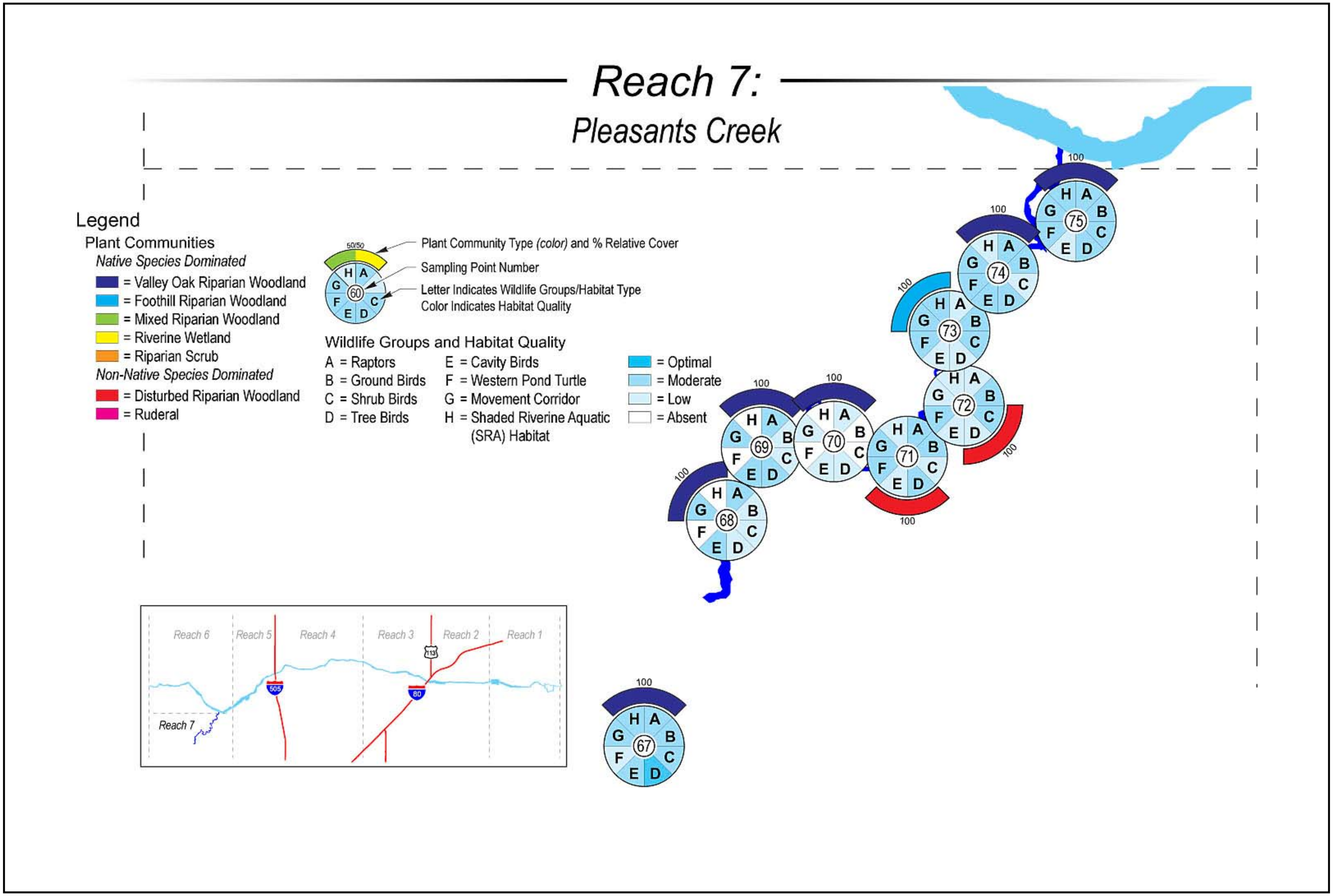
Plant Communities and Wildlife Habitat Quality

EXHIBIT 6-1f

Lower Putah Creek Watershed Management Action Plan

P 1T136.02 08/03

EDAW



Source: EDAW 2004

Plant Communities and Wildlife Habitat Quality

EXHIBIT 6-1g

Lower Putah Creek Watershed Management Action Plan

P 1T136.02 08/03

EDAW

Much of lower Putah Creek can be characterized as having varying amounts of mixed riparian forest and valley oak riparian forest, riparian scrub, and other plant community types. However, there are some shifts in community type, primarily in the upper reaches. The interdam reach (Reach 6) is dominated by mixed riparian woodland, and Pleasants Creek (Reach 7) is dominated by valley oak riparian woodland. Several reaches have major infestations of nonnative invasive weeds, forming woodland communities dominated by nonnative species, especially in Reach 4, upstream of Stevensons Bridge.

Most of the invasive weeds documented during surveys occur in more than one plant community. Some of the primary invasive weed species in lower Putah Creek are eucalyptus (*Eucalyptus* spp.) and tree-of-heaven (*Ailanthus altissima*) in the tree layer; Himalayan blackberry (*Rubus discolor*), tamarisk (*Tamarix* spp.), and arundo (aka: giant reed) (*Arundo donax*) in the shrub layer; perennial pepperweed (*Lepidium latifolium*) and yellow star-thistle (*Centaurea solstitialis*) in the herb layer; and water milfoil (*Myriophyllum* sp.) in the creek channel.

The characteristics and distribution of invasive weeds along lower Putah Creek and Pleasants Creek are provided in detail in Chapter 7, "Invasive Weeds."

6.3.1 Mixed Riparian Forest

The most common plant community in the lower Putah Creek and Pleasants Creek riparian corridor is mixed riparian forest (See Exhibit 6-2 for a representative photo). The width and complexity of mixed riparian forest varies and is characterized by one or more well-developed canopy layers. When present, the highest canopy layer is generally open and dominated by tall Fremont cottonwood trees. The next canopy layer, frequently the uppermost, is typically moderately dense and composed of tree species such as valley oak, Oregon ash, Goodding's willow, and box elder. In some areas of the creek, there is a subcanopy layer of dense riparian scrub dominated by willow species including Arroyo willow (*Salix lasiolepis*) and sandbar willow (*S. exigua*). A discontinuous shrub layer is generally present within the mixed riparian forest including species such as blue elderberry (*Sambucus mexicana*), button bush (*Cephalanthus occidentalis*), Himalayan blackberry (*Rubus discolor*), wild rose (*Rosa californica*), poison oak (*Toxicodendron diversilobum*), and wild grape (*Vitis californica*). A sparse to densely vegetated ground layer, when present, typically includes grasses such as creeping wildrye (*Leymus triticoides*) and forbs such as mugwort (*Artemisia douglasiana*). Seedlings of many of the tree species mentioned above could also be found in the understory.

Many invasive weeds have colonized the mixed riparian forest, including tamarisk, arundo, and tree-of-heaven in the subcanopy and shrub layers, and Northern California black walnut (*Juglans californica* var. *hindsii*) hybrids in the upper canopy. The characteristics and distribution of these invasive weeds are provided in detail in Chapter 7, "Invasive Weeds."

6.3.2 Valley Oak Riparian Forest

Valley oak riparian forest occurs most commonly on the upland terraces and high floodplains of the creek adjacent to mixed riparian forest, with which it often intergrades. Valley oak

Mixed riparian forest

Riparian scrub along banks and valley oak riparian forest at top of bank

Source: EDAW 2003

Riparian Communities

EXHIBIT 6-2

EDAW

riparian forest typically grows in locations above the active creek channel that are less subject to physical disturbance (e.g., scour) from flooding but still receive annual inputs of silty alluvium and subsurface irrigation (Holland 1986). Along Putah Creek, valley oak riparian forest is characterized by a single, moderately-tall canopy layer that is relatively open and dominated by valley oak with some interior live oak (*Quercus wislizenii*) occasionally present. The Valley oak riparian forest canopy sometimes has other tree species present which are often associated with mixed riparian forest, including box elder, Oregon ash, and invasive Northern California black walnut hybrids. The shrub layer is generally sparse and includes poison oak, blue elderberry, wild rose, wild grape, and California pipevine (*Aristolochia californica*). The understory typically has young valley oak and walnut seedlings. The ground layer, when present, has a range of species, from those found in mixed riparian forest to species found in drier conditions.

6.3.3 Disturbed Riparian Woodland

Disturbed riparian woodland is dominated by invasive tree species such as *Eucalyptus* and tree-of-heaven (Exhibit 6-3). *Eucalyptus* tends to exclude other species. Its leaves and roots alter the soil chemistry and inhibit the germination and growth of other species. However, disturbed riparian woodland can also include native tree, shrub, and herbaceous species.

Invasive weeds can quickly proliferate and displace native plant populations and contribute to a loss of habitat to native wildlife dependent on those plants. Invasive weeds can also affect the balance of natural processes such as the frequency and extent of fires, flooding, sediment transport, erosion and channel formation, and nutrient cycling. Such alterations can contribute to further habitat loss and damage human infrastructure and land uses causing economic hardship and safety concerns.

6.3.4 Riparian Scrub

Riparian scrub occurs adjacent to the creek channel. In general, it consists of an open to dense shrubby thicket dominated by a mixture of sandbar willow, arroyo willow, and red willow (Exhibits 6-1a through 6-1g and Exhibit 6-2). This plant community sometimes forms a subcanopy in mixed riparian forest. Dense stands of riparian scrub typically lack an understory, while more open stands sometimes support an understory of Himalayan blackberry, wild rose, wild grape, and nonnative grasses. In addition, areas supporting early seral (i.e., pioneer or young) stage stands of mixed riparian forest are considered riparian scrub because of the shrub-like stature of the trees.

6.3.5 Foothill Riparian Woodland

This plant community is transitional in nature and includes elements of both foothill woodland and mixed riparian forest. Foothill riparian woodland occurs along Putah Creek near the Monticello Dam. The canyons surrounding the creek in this area are relatively steep and support foothill woodland vegetation, characteristic of the east slope of the coastal foothills. This area appears to be much less disturbed than other areas along the creek, as evidenced by the scarcity of invasive weed infestations. Foothill woodland has a tall, open canopy dominated

Invasive arundo-covered streambank

Disturbed bank, rocks and invasive tree-of-heaven intermixed with native vegetation

Source: EDAW 2003

Disturbed Riparian Communities

EXHIBIT 6-3

EDAW

by foothill pine (*Pinus sabiniana*) and interior live oak, along with lesser amounts of canyon live oak (*Quercus chrysolepis*). The taller trees are interspersed with a subcanopy consisting of scattered shrubs and small trees, including toyon (*Heteromeles arbutifolia*), redbud (*Cercis occidentalis*), sticky monkeyflower (*Mimulus aurantiacus*), and California fuchsia (*Epilobium canum*). The ground layer consists of valley grassland species and woodland herbs. Fremont cottonwood and foothill pine dominates the creek edge, interspersed with an understory of scattered willows, foothill woodland shrubs, and a ground layer consisting of grasses and forbs such as mugwort.

6.3.6 RIVERINE WETLAND

Riverine wetland along Putah Creek includes seasonal and perennial wetlands along the creek channel and lower bank, instream wetlands that formed on sand or gravel bars, and patches of emergent freshwater marsh (Exhibit 6-4). Riverine wetlands are dynamic, herb-dominated plant communities that are influenced by frequent flooding, scour, and creek water level fluctuations that occur on a seasonal and annual basis. Species common to this plant community include wetland plants such as smartweed (*Polygonum* spp.), umbrella sedge (*Cyperus eragrostis*), sedges (*Carex* spp.), common rush (*Juncus effusus*), mugwort, cocklebur (*Xanthium strumarium*), rice cutgrass (*Leersia oryzoides*), canarygrass (*Phalaris* spp.), field mint (*Mentha arvensis*), and western goldenrod (*Euthamia occidentalis*), as well as large emergent perennials such as cattails (*Typha angustifolia*) and tule (*Scirpus acutus*). Invasive weeds, including *Arundo* and tamarisk, also occur on sand or gravel bars in the creek.

6.3.7 OPEN WATER

Open water habitat includes the creek channel, side-channel ponds, and habitats around Lake Solano. The density of vegetation in open water areas varies considerably. For instance, portions of the channel just below Lake Berryessa lack vegetation altogether, but many downstream areas are characterized by high aquatic plant cover. Common floating plant species in lower Putah Creek included water milfoil (*Myriophyllum* sp.), floating water-primrose (*Ludwigia peploides*), waterweed (*Elodea* sp.), and curly pondweed (*Potamogeton crispus*). The character of the open water aquatic plant community also varies from season to season and year to year, depending on the flow and flooding pattern, temperature, and availability of propagules. That is, in some years invasive weeds such as water hyacinth (*Eichhornia crassipes*) may dominate, while in other years, such as during the sampling period, weeds such as water milfoil may dominate. In addition, the amount of agricultural runoff, which can contain concentrated nutrients such as nitrogen and phosphorus, varies seasonally and may influence the aquatic plant community.

6.3.8 RUDERAL AREAS

Ruderal areas consist of disturbed areas that have been stripped of their natural vegetative cover. These areas are either covered by gravel or dirt or dominated by nonnative herbs such as yellow star-thistle (*Centaurea solstitialis*), milk thistle (*Silybum marianum*), Italian thistle (*Carduus pycnocephalus*), prickly lettuce (*Lactuca serriola*), mustard species (*Brassica nigra, Hirschfeldia incana*), soft chess (*Bromus hordeaceus*), ripgut brome (*Bromus diandrus*), and wild oat

Riparian corridor, riverine wetland, and open water

Riparian corridor in the background and freshwater marsh in the foreground

Source: EDAW 2003

Riverine Wetland

EXHIBIT 6-4

(*Avena fatua*). Ruderal vegetation typically occurs on the upland periphery of the riparian corridor where the natural vegetation has been disturbed by adjacent land uses.

6.3.9 AGRICULTURAL LAND

Throughout most of lower Putah Creek, including its tributaries, there is considerable agricultural land adjacent to the riparian corridor. Typical agricultural uses include walnut and almond orchards, row crops such as tomatoes, and fallow fields. A discussion of the agricultural land and other land uses along lower Putah Creek and Pleasants Creek is found in Chapter 3, "Land Ownership, Land Use, and Resource Management Programs."

6.3.10 DEVELOPED AREAS

Developed areas along lower Putah Creek and Pleasants Creek include residential houses and yards, a landscaping business storage yard, roads, bridges, fishing access facilities, parking areas, developed parks, dams (excluding reservoir areas), and other developed plots within the riparian corridor. Most developed land along lower Putah Creek and its tributaries lies outside but often near the riparian corridor. Developed areas are typically lacking in vegetation cover. Where vegetation exists, it ranges from a sparse cover of native vegetation to horticultural plantings, including both invasive (e.g., *Catalpa*, black locust, and *Eucalyptus*) and non-invasive species (e.g., *Toyon* and western redbud).

6.4 EXISTING WILDLIFE HABITATS

This section discusses the importance of Putah Creek's riparian habitat to wildlife, including an analysis of riparian corridor size, potential for wildlife movement, SRA cover, and an assessment of existing wildlife habitat quality for the western pond turtle, raptors, and other nesting birds. These assessments are based on field evaluations conducted at 75 sampling points as described under Section 6.1 "Methods," above. A list of bird species observed along lower Putah Creek during the breeding season (approximately February through August) is provided in Appendix E.

6.4.1 GENERAL RIPARIAN HABITAT VALUE

Riparian habitats support the most diverse wildlife communities of any habitat type in California (Mayer and Laudenslayer 1988, RHJV 2000). Over 225 species of birds, mammals, reptiles, and amphibians depend on riparian habitats for nesting, foraging, dispersal corridors, and migration stop-over sites. Riparian vegetation is also critical to the quality of instream aquatic life. It provides shade, food, and nutrients that form the basis of the food chain (RHJV 2000). Riparian vegetation also supplies instream habitat when high flows dislodge trees and patches of willows, creating pools where the creek bed and bank vegetation is scoured. The downed trees also form logjams important for fish, semi-aquatic reptiles and amphibians, and aquatic insects. Riparian habitats may also be the most important habitat for bird species in California (Gaines 1977, RHJV 2000).

6.4.2 RIPARIAN CORRIDOR AREA ANALYSIS

The width of the riparian corridor is an important characteristic for assessing wildlife and fish habitat quality. It is used as a criterion in the evaluation of riparian nesting bird habitat and wildlife movement corridor function. For this WMAP, we define the riparian corridor as the area extending from each creek bank to its adjacent upland area, agricultural lands in most cases. The average width of the riparian corridor in 1-mile intervals along lower Putah Creek and Pleasants Creek is indicated in Table 5-8 in Chapter 5, "Fisheries."

The riparian corridor along lower Putah Creek is generally narrow. Its current extent of less than 2,000 acres for the entire watershed, with an average width of less than 334 feet, is greatly reduced from its pre-development estimated size of between 22,000 and 65,000 acres and 1.5 miles average width for the area between Winters and the Putah Creek sinks (Katibah 1984, Kuchler 1977, USFWS 1993).

Riparian corridor width currently ranges from 71 feet to 807 feet per river mile, divided between both sides of the creek. This equates to acreage values ranging from 10 to 100 acres per river mile. Throughout most of the watershed, however, the corridor varies from about 250 to 400 feet wide, divided between both sides of the creek. The most extensive moderately-wide (448 – 807 feet) stretch of riparian corridor area is located within Reach 6, downstream of the PDD. The longest continuous stretch of very narrow corridor area is located along Pleasants Creek, where the corridor varies from 102 to 148 feet wide.

6.4.3 SPECIFIC RIPARIAN HABITAT ASSESSMENTS

Overall, habitat quality for all wildlife groups is moderate. Exhibits 6-1a through 6-1g show the results of the vegetation classification and wildlife habitat quality assessments at sampling locations by reach. Table 6-1 shows the percent of sampling sites assigned to each habitat quality level for each wildlife group considered. The groups are discussed in more detail in the following sections.

Table 6-1
Percent of Sampling Sites Comprising Each Wildlife Group Habitat Quality Level

	Optimal	Moderate	Low	Absent
Raptors	9	53	35	3
Ground-nesting birds	7	59	33	1
Shrub-nesting birds	15	63	21	1
Tree-nesting birds	8	68	24	0
Cavity-nesting birds	0	55	41	4
Western Pond Turtle	3	64	29	4
Wildlife Movement Corridor	17	62	21	0
SRA Cover	7	66	20	7

Source: EDAW 2003

Table 6-2 shows the locations of high- and low-quality habitats by functional groups. Detail on each functional group follows.

Table 6-2
Comparison of Locations of High- and Low-Quality Habitats by Functional Groups

Functional Group	High-Quality Habitat	Low-Quality Habitat
Raptors	East of I-80 (Reaches 1 & 2)	Near Hwy 505 (Reach 4 and 5) at I-80 (Reach 2)
Tree-Nesting Birds	Upstream of Stevensons Bridge (Reach 4); Upstream portion of Reach 6	Lake Solano (Reach 6) Downstream of I-505 (Reach 4)
Shrub-Nesting Birds	Downstream of Monticello Dam (Reach 6) Downstream of PDD (Reach 5)	Los Rios Check Dam
Ground Nesting Birds	Upstream portion of Reach 6	Pedrick Rd. to SR 113 Lake Solano (Reach 6)
Cavity-Nesting Birds	None, but many areas of moderate habitat	I-80 to Mace Blvd. (Reach 2) Downstream of Hwy 505 (Reach 4) Lake Solano (Reach 6)
Western Pond Turtles	Downstream of Stevensons Bridge (Reach 3); Downstream of I-80 (Reach 2)	Pleasants Creek (Reach 7)
Corridor Width	Upstream of confluence between Putah Creek and Bypass (Reach 1); Reach 5	Yolo Bypass (Reach 1)
Shaded Riverine Aquatic	Upstream from Lake Solano (Reach 6)	Lake Solano (Reach 6) Pleasants Creek (Reach 7) Yolo Bypass (Reach 1)
Movement Corridor	Middle of Reach 2; Downstream of Putah Creek Diversion Dam (Reach 5)	Lake Solano (Reach 6)
Native Riparian Woodland	Reach 1; Middle of Reach 4; Reach 6	Upstream of Stevensons Bridge (Reach 4)
Source: Truan 2005.		

RAPTORS

Habitat quality for raptors along lower Putah Creek and Pleasants Creek is considered to be moderate (53% of all sampled locations) to low (35% of sampled locations), with only 9% of sampled locations considered to be optimal habitat. The area east of I-80 (Reaches 1 and 2) has the highest quality habitat, with almost all sampling points in these reaches classified as moderate or optimal (Exhibits 6-1a and 6-1b). These areas have large trees that could support nests, have suitable foraging habitat near potential nesting locations, and have relatively low disturbance from adjacent land uses, such as residential or commercial development or major roadways. The presence of alfalfa and certain other crops adjacent to the riparian corridor within the levees provides high-quality foraging habitat for raptors because these crops incidentally support higher concentrations of rodents than native vegetation. Areas classified as moderate or low tend to have fewer suitable nest trees, adjacent foraging areas may be limited, or nearby land uses may be a potential disturbance. Habitat was considered absent, because of the lack of any potential nest trees and low-quality foraging habitat, at two sampling locations upstream from Winters in Reach 6 and at I-80 in Reach 2 (Exhibit 6-1f).

OTHER NESTING BIRDS

For ground-nesting birds, most (59%) of the sampling locations showed moderate habitat quality. These areas have adequate nesting substrate, a relatively wide area of riparian vegetation along the creek corridor, good vegetative structural complexity, and relatively low apparent density of predators/disturbance or attractants for predators (e.g., see Exhibit 6-2). Optimal habitat for ground-nesters occurs upstream, in Reach 6 (Exhibit 6-1f). Areas of low-quality habitat occur in scattered locations along the creek, mainly from Pedrick Road to Highway 113 (Reach 3) and near Lake Solano in Reach 6. These areas were considered to provide low-quality habitat because of fair to poor availability of suitable nesting substrate in the ground layer of vegetation, residential or other development encroachment along the riparian corridor, and a lack of structural complexity in the understory layer (Exhibit 6-1c).

A similar trend was observed for shrub-nesting birds, with most of the creek classified as moderate habitat quality (63% of sampling locations) (Exhibit 6-2). The criteria used to evaluate habitat quality were similar for ground-, shrub-, tree-, and cavity-nesting birds, except that the nesting substrate locations were different. Optimal habitat for shrub-nesting birds includes an adequate nesting substrate (e.g., blackberry, California rose, mugwort, wild grape, and tree saplings in the shrub layer), a complex vegetation structure, a relatively wide riparian corridor, and a low density of predators with few disturbances. Optimal habitat occurs downstream of Monticello Dam in Reach 6, and a few areas downstream of the PDD in Reach 5 (Exhibit 6-1f). Scattered areas of low-quality habitat exist along the entire study area. However, more areas are considered optimal (15% of sampling locations) and fewer considered low-quality, for shrub-nesters than for ground-nesters. The largest stretch of low-quality habitat for shrub-nesters is located near the Los Rios Check Dam in the Yolo Bypass area, where the shrub layer is underdeveloped or lacking (Exhibit 6-1a).

Habitat for tree-nesting birds is also mostly considered moderate (68% of sampling locations). Habitats of moderate quality are often interspersed with some areas of optimal (Exhibit 6-3) or low-quality habitat. Optimal habitat for tree-nesting birds is similar to that for shrub-nesting birds. Tree-nesting birds nest in willow, cottonwood, box elder, and black walnut trees. Areas of low-quality habitat for tree-nesting birds occur near Lake Solano in Reach 6 (Exhibit 6-1f) and downstream of I-505 in Reach 4 (Exhibit 6-1d). In general, these areas have poor availability of suitable trees for cup-nesters, the structural complexity of the riparian vegetation and the riparian corridor width is poor to fair, and the apparent density of predators/ disturbance or attractants for predators is high.

Habitat for cavity-nesting birds along Putah Creek is of moderate to low quality, with no areas of optimal habitat recorded. In a few locations, habitat for cavity-nesters was absent. Cavity-nesting birds nest in trees with holes, areas with rotten or broken limbs, and snags. Otherwise, optimal habitat for cavity nesters is similar to that discussed for other nesting birds. The areas near Lake Solano (Reach 6), the confluence of Pleasants Creek with Putah Creek (Reach 7), downstream of I-505 (Reach 4), and downstream of I-80 (Reach 2) had consistently low-quality habitat at the sampling locations, because of the lack of snags or trees with cavities (Exhibits 6-1f, 6-1g, 6-1d, and 6-1b). Areas of moderate habitat were located in Reaches 1, 3, and 5 (Exhibits 6-1a, 6-1c, and 6-1e).

WESTERN POND TURTLE

The Western Pond Turtle is a relatively common semi-aquatic reptile species along Putah Creek; therefore, habitat quality for pond turtles was included in the assessment. Other reptile and amphibian species may require different habitat attributes and the classification for pond turtles may not accurately portray the habitat quality for these species. A good overview of reptiles and amphibians that occur within the Putah Creek watershed can be found in the *Putah Creek News* article, "Meet the amphibians and reptiles of the lower Putah Creek watershed" (Barry 2000).

Most sampling locations are classified as moderate or low quality for western pond turtles. Many areas of Putah Creek have slack or slow-moving water, with aerial basking areas such as logs, rocks, and exposed banks. Areas of moderate-quality habitat also have dense submergent vegetation (e.g., pondweed and ditch grass) for basking and feeding. However, most sampling sites lack suitable upland nesting sites (i.e., open grassy areas up to 1,300 feet from aquatic habitat). A lack of suitable habitat was also observed for portions of Pleasants Creek, where all aquatic habitat had dried up by late summer (Exhibit 6-1g).

SHADED RIVERINE AQUATIC COVER

SRA cover habitat is classified as moderate quality for most of the study area (Exhibit 6-1a through 6-1f). In general, these areas had good to fair amounts of high (e.g., trees and shrubs) and low (e.g., sedges) vegetation that overhang the water, instream vegetative debris (e.g., leaves, branches, and logs), and naturally eroding banks with undercuts (Exhibit 6-3). The largest areas of low-quality SRA cover habitats were located along Lake Solano in Reach 6 and along Pleasants Creek in Reach 7 (Exhibit 6-1f and 6-1g). For more details, see the discussion of SRA cover in Chapter 5, "Fisheries."

WILDLIFE MOVEMENT CORRIDOR

A wildlife movement corridor is a linear habitat whose primary wildlife function is to connect two or more areas of suitable habitat. As such, connectivity of riparian woodland is a critically important characteristic. Putah Creek is one of the few drainages that connect the Coast Range to open-space preserves (i.e., Yolo Bypass Wildlife Area) on the Central Valley floor. Riparian connectivity provides cover that enables dispersal or exploratory movement by mammals through a landscape dominated by agricultural and urban land uses. (Exhibits 3-1 and 3-2 in Chapter 3, "Land Ownership, Land Use, & Resource Management Programs," depict selected wildlife areas and reserves, and existing land uses in the region). Although wildlife may move through adjacent agricultural fields and orchards, they risk greater potential predation or harassment from dogs, cats, and people.

Putah Creek provides movement for small and medium-size mammals, such as beaver and river otter, and large mammals such as deer. On two known occasions during the 1980s, mountain lions were sighted on the UC Davis campus and a black bear was reported along Putah Creek at Pedrick Road in 1998 (Boyer et al. 2001). Presumably, these animals originated from Putah Creek's headwaters in the coastal mountain forests. Although these species have been incidentally observed using the riparian corridor, it is not expected that they would regularly occur because the habitat is not considered suitable to support large predators. However, movement of smaller mammals, such as skunks, opossums, and raccoons, likely occurs regularly and may be important in maintaining local populations. Scattered obstacles to movement occur along the creek, primarily near residential settlements, bridges, or freeways that have sparse vegetative cover and a narrow riparian corridor. An area of particularly low-quality habitat for dispersal occurs along Lake Solano. Campsites and parking lots within the riparian corridor likely restrict wildlife movement along the south bank, while on the north bank Highway 128 runs along the edge of the creek and confines the narrow fringe of riparian vegetation to the south side of the roadway.

6.5 SENSITIVE BIOLOGICAL RESOURCES

Sensitive biological resources are afforded special protection through the California Environmental Quality Act (CEQA), California Fish and Game Code, federal and state Endangered Species Acts, and the Clean Water Act (CWA). A summary of these regulations is provided in Appendix H. Special-status species include plants and animals that are legally protected or considered sensitive by federal, state, or local resource conservation agencies and organizations. These include species that are state and/or federally listed as Rare, Threatened, or Endangered, those considered as candidates or proposed for listing, species identified by DFG and/or USFWS as species of concern, and plants considered by the California Native Plant Society (CNPS) to be Rare, Threatened, or Endangered. Sensitive natural communities include those that are especially diverse, regionally uncommon, or of special concern to local, state, and federal agencies.

A list of special-status species that have the potential to occur in the project area was developed by reviewing DFG's California Natural Diversity Data Base (DFG CNDDB 2003a) and CNPS Electronic Inventory of Rare and Endangered Plants (CNPS 2002) for the Monticello Dam, Mt. Vaca, Winters, Merritt, Davis, and West Sacramento 7.5 minute geographic quadrangles, and consultation with local experts and agency personnel. There are 10 special-status wildlife species and one special-status plant species with potential to occur in the study area. Table 6-3 provides information on special-status wildlife species that may occur in the watershed study area, though the occurrence of some of these would be highly unlikely. Special-status wildlife species that might realistically be expected to occur in the study area today include: valley elderberry longhorn beetle (VELB), foothill-yellow legged frog, western pond turtle, giant garter snake, tricolored blackbird, burrowing owl, Swainson's hawk, white-tailed kite, yellow-breasted chat, and Modesto song sparrow. Each of these species is discussed briefly below. The only special-status plant species with potentially suitable habitat in the study area is rose-mallow (*Hibiscus lasiocarpus*), described briefly following the special-status wildlife species. Although not a special-status plant species, blue elderberry is protected because of its function as habitat for VELB. Special-status fish species are described in Chapter 5, "Fisheries."

Table 6-3
Special-Status Wildlife Species with Potential to Occur in the Lower Putah Creek Watershed

Species	Habitat	Potential for Occurrence	DFG	USFWS
INVERTEBRATES				
VALLEY ELDERBERRY LONGHORN BEETLE *Desmocerus californicus dimorphus*	elderberry shrubs	Known to occur in study area; elderberry shrubs are present.	---	FT
AMPHIBIANS				
CALIFORNIA TIGER SALAMANDER *Ambystoma californiense*	vernal pools and permanent waters in grasslands	Not expected to occur. No suitable breeding habitat in study area; however, known to occur in west Davis area.	CSC	FT
CALIFORNIA RED-LEGGED FROG *Rana aurora draytonii*	deep water ponds with overhanging vegetation	Not expected to occur in the study area. Presumed extirpated from the area; however, known to occur in several locations near Cordelia and Fairfield in Solano County.	CSC	FT
FOOTHILL YELLOW-LEGGED FROG *Rana boylii*	Partly shaded, shallow streams and riffles with cobble-sized substrate.	Could occur in the study area. Known to occur in Cold Canyon Creek and could potentially occur in the inter-dam section of lower Putah Creek.	CSC	FSC
REPTILES				
WESTERN POND TURTLE *Emys marmorata*	ponds, marshes, streams, and irrigation ditches	Known to occur in the study area.	CSC	FSC
GIANT GARTER SNAKE *Thamnophis gigas*	Freshwater marsh and low gradient streams. Also irrigation ditches and canals. Needs upland habitats for winter dormancy	Could potentially occur in lower portion of study area. Known to occur in Willow Slough and the Yolo Bypass area (DFG 2003a).	CT	FT

Table 6-3
Special-Status Wildlife Species with Potential to Occur in the Lower Putah Creek Watershed

Species	Habitat	Potential for Occurrence	DFG	USFWS
BIRDS				
TRICOLORED BLACKBIRD *Agelaius tricolor*	freshwater marsh, blackberry thickets, and nonnative thistle	Known to occur near Winters and elsewhere in Yolo and Solano counties; some potential to occur adjacent to riparian corridor of lower Putah Creek.	CSC	FSC
BURROWING OWL *Athene cunicularia*	grasslands and agricultural areas	Known to nest and winter adjacent to Putah Creek. Suitable nesting habitat present at edges of agricultural fields bordering the creek.	CSC	FSC
SWAINSON'S HAWK *Buteo swainsoni*	grasslands, riparian woodlands, and agricultural fields	Known to nest in mature trees in the study area.	CT	---
WHITE-TAILED KITE *Elanus leucurus*	grasslands, open woodlands	Known to nest in trees in the study area.	CSC	---
YELLOW-BREASTED CHAT *Icteria virens*	Riparian thickets of willow, blackberry, wild grape, and other brushy tangles near watercourses	Reported to occur during breeding season near Pleasants Creek in 1987 (DFG 2003a). May also occur in study area during migration.	CSC	---
MODESTO SONG SPARROW *Melospiza melodia mailliardi*	Moderately dense riparian vegetation, near water source, with patches of open ground for foraging	Known to nest in the study area. May also occur year-round in the study area.	PSC	---

U.S. Fish and Wildlife Service (USFWS) Federal Listing Categories:
FSC Federal Species of Concern - Species of concern to the Sacramento Fish and Wildlife Office (no formal protection)
FT Federal Threatened

California Department of Fish and Game (DFG) State Listing Categories:
CT California Threatened
CSC California Species of Concern
PSC Proposed Species of Concern

6.5.1 SPECIAL-STATUS WILDLIFE

VALLEY ELDERBERRY LONGHORN BEETLE

The valley elderberry longhorn beetle (VELB) is federally-listed as Threatened. This beetle requires blue elderberry shrubs (*Sambucus mexicana*) for reproduction and survival. Blue elderberry shrubs are common in the riparian vegetation along Putah Creek. Valley elderberry longhorn beetles are rarely seen because they spend most of their life cycle as larvae within the stems of elderberry shrubs. Often the only evidence of the beetles' presence are exit holes created by the larvae just prior to the pupal stage. Adult emergence is from late March through June. During this period, adults mate, lay eggs, and die.

DFG's CNDDB (DFG 2003a) includes a recent sighting of an adult VELB at the PGT-Pacific Gas & Electric gas line crossing site near the City of Winters (occurrence #131), as well as older collections along the creek above Lake Solano in 1975 and 1985 (occurrence #3), and in Cold Canyon in 1982 (occurrence #12). In addition to these sightings of adults, exit holes have been observed at many locations along the creek, including from the Monticello Dam to the PDD, east of I-505, and on Pleasants Creek near the Pleasants Valley Road bridge (EDAW 2002, DFG 2003a). Researchers at UC Davis are currently conducting VELB surveys on some properties along Putah Creek.

Two areas in Sacramento County along the Sacramento and American rivers have been identified as critical habitat because they harbor the densest known populations of beetles in the region (USFWS 1980). Putah Creek was considered for designation as critical habitat, but was withdrawn because of lack of information on the population in that area. However, essential habitat was identified in the recovery plan for VELB in Reach 6 between the Monticello Dam and Lake Solano (USGS 7.5 minute Monticello Dam quadrangle, Township 8 North, Range 2 West, Sections 25, 26, 35 and 36) (USWFS 1984).

FOOTHILL YELLOW-LEGGED FROG

The foothill yellow-legged frog is a federal and California Species of Special Concern. Foothill yellow-legged frogs are characteristically found close to water in association with perennial streams and ephemeral creeks that retain perennial pools through the end of summer. They require shallow, flowing streams with some cobble-sized substrate on which they deposit large masses of eggs. In coastal areas, egg masses are often laid along stream margins in sunny, open areas of shallow (usually less than 3 feet) water. Egg-laying normally follows the period of high-flow discharge associated with winter rainfall, usually between late March and early June. Eggs hatch in about 15 to 30 days depending on water temperature, and tadpoles metamorphose into juvenile frogs in 3 to 4 months. Populations of foothill yellow-legged frogs are threatened by loss of habitat and introduced aquatic predators.

The distribution of foothill yellow-legged frogs in the lower Putah Creek watershed is not known, as comprehensive surveys have not been conducted. Competition with introduced species, especially bullfrogs (*Rana catesbeiana*), likely occurs, but its effects are unknown.

Yellow-legged frogs are known to occur in the Cold Canyon tributary, however, and may stray into areas of suitable habitat in the inter-dam area of Putah Creek (DFG 2003a, Barry 2000).

GIANT GARTER SNAKE

The giant garter snake is federally and state listed as a Threatened species. Giant garter snakes inhabit a variety of aquatic habitats, such as agricultural canals, marshes, sloughs, and ponds. They also require adjacent upland habitat for basking and rodent burrows for overwintering that provide sufficient cover and are at high enough elevations to function as refuges from flood waters during the snakes' inactive season. Giant garter snakes are typically absent from larger rivers and from wetlands with sand, gravel, or rock substrates. Riparian woodlands do not typically provide suitable habitat because of excessive shade, lack of basking sites, and absence of prey populations (USFWS 1999). Essential habitat components for giant garter snake consist of the following:

- sufficient water during the snake's active season (early spring through mid-fall) to provide adequate permanent water to maintain dense populations of food organisms;
- emergent, herbaceous wetland vegetation, such as cattails and bulrushes, for escape cover and foraging habitat during the active season;
- upland habitat with grassy banks and openings in waterside vegetation for basking; and
- higher elevation upland habitats for cover and refuge from flood waters during the snake's inactive season.

Although these four components comprise the optimal habitat for the complete life cycle of the giant garter snake, the species may use areas with only one of these components on a temporary or seasonal basis.

Giant garter snakes are not expected to occur in much of Putah Creek where there are well-developed riparian woodlands. They are more likely to occur in areas where the creek is slow-moving and slough-like and where vegetation is ruderal or scant. They were reported to occur in 1976 on the South Fork of Putah Creek at Old Davis Road, but were not seen during surveys in 1986–1987 (DFG 2003a). Giant garter snakes have more recently been reported in vegetated irrigation ditches near rice fields north of Davis on the Conaway Ranch in 1990, 7 miles south-southeast of Woodland in 1987, and in the Willow Slough Bypass approximately 4.5 miles northeast of Putah Creek and I-80 in 1990 (DFG 2003a). Two populations of giant garter snakes are known to occur in rice production areas along the western edge of the Yolo Bypass in Yolo and Solano counties: one in Willow Slough in the northern area of the Bypass and the other in the Liberty Farms area (USFWS 1999). Because the water in Putah Creek in the Yolo Bypass is slow moving and the riparian vegetation is not well developed, there is potential for individuals from the Willow Slough population to be found in the Bypass area of lower Putah Creek also.

WESTERN POND TURTLE

The western pond turtle is a federal Species of Concern and a California Species of Special Concern. Pond turtles generally occur in streams, ponds, freshwater marshes, and lakes. They require still or slow moving water with instream emergent woody debris, rocks, or other similar features for basking sites. Nests are typically located on unshaded upland slopes in dry substrates with clay or silt soils.

Western pond turtles are frequently observed in many locations along Putah Creek, especially along the North Fork on the UC Davis campus arboretum. The CNDDB also reports pond turtles on Putah Creek downstream from Winters (DFG 2003a).

The Central Valley once may have been the area of greatest western pond turtle density within their range. However, extensive draining of wetlands and habitat alteration in the past century have left few aquatic areas that are suitable for this species. Several researchers have noted that several Central Valley populations may be at risk of serious decline because they were composed of non-reproducing old adults and no small turtles had been observed during visual surveys (USFWS 1992, Jennings and Hayes 1994). However, a recent study conducted throughout the Central Valley revealed that at several sites where turtles were abundant, the population included young, but large individuals (Germano and Bury 2001). Although the authors concluded that current pond turtle abundance falls at a small fraction of historical levels, recruitment does appear to be occurring.

TRICOLORED BLACKBIRD

The tricolored blackbird is a federal Species of Concern and a California Species of Special Concern. Tricolored blackbirds nest colonially and have three basic requirements for selecting their breeding colony: (1) open accessible water, (2) a protected nesting substrate that is usually either flooded or characterized by thorny or spiny vegetation, and (3) a suitable foraging area providing adequate insect prey near the nesting colony, such as agricultural fields and grasslands (Beedy and Hamilton 1997). Studies conducted in the early 1900s documented that almost all nests were located in freshwater marshes dominated by tules and cattails, with remaining nests in willows, blackberries, thistles (*Cirsium* and *Centaurea* spp.), or nettles (*Urtica* spp.) (Beedy and Hamilton 1997). However, more recent research has documented an increasing trend for colonies to nest in Himalayan blackberry, and other plants used for silage (i.e., crops that are harvested when green and stored and allowed to ferment for use as animal feed) and grain fields. Table 6-4 summarizes this change in use of nesting substrate (Cook and Toft 2005). A recent study on nesting success has shown that colonies in Himalayan blackberries have much greater reproductive success than colonies using other substrates, including freshwater marsh (Cook and Toft 2005). The Riparian Bird Conservation Plan (RHJV 2000) recommends that any management efforts to remove blackberry from riparian areas (i.e., invasive weed removal programs) should first assess any detrimental effects the removal may have on local breeding bird populations.

Tricolored blackbirds are known to forage in agricultural fields adjacent to Putah Creek, but no nesting colonies are known to occur in the riparian corridor along the creek. There are no DFG 2003a records of past colonies along lower Putah Creek. There are approximately 16 historical and current colonies reported in Yolo and Solano counties (DFG 2003a). The locations of the colonies are considered sensitive by DFG because of their vulnerability to disturbance. Although tricolored blackbirds are not known to nest along Putah Creek, they are known to occur in the area and nesting in the lower Putah Creek watershed could also occur if suitable habitat were present.

Table 6-4
Proportion of Individuals and Colonies of Tricolored Blackbirds by Nesting Substrate from the 1930s to 2000

Nesting Substrate	1932–1934 [1]		1968–1972 [2]		1994–2000 [3]	
	% of colonies	% of total birds	% of colonies	% of total birds	% of colonies	% of total birds
Emergent marsh	94.8	92.7	69.7	n/a	52.3	41.0
Himalayan blackberry	1.3	0.1	16.1	n/a	25.1	14.8
Silage	0.0	0.0	0.0	n/a	4.9	29.6
Other flooded plants	1.3	0.2	5.8	n/a	6.9	5.5
Other protecting plants	2.6	7.0	9.0	n/a	10.7	8.9
Total native plants	96.7	93.0	75.5	n/a	64.7	46.4
Total nonnative plants	3.3	7.0	24.5	n/a	35.2	53.6

[1] Data from Neff (1937) from the Sacramento Valley and northern San Joaquin Valley.
[2] Statewide data from DeHaven et al. (1975).
[3] Statewide data from Cook and Toft 2005).
Source: Cook and Toft 2005)

BURROWING OWL

The burrowing owl is a federal Species of Concern and a California Species of Special Concern. This species is also protected under §3503.5 of the California Fish and Game Code, which prohibits the destruction of raptors and their nests. Burrowing owls prefer dry grasslands and other dry, open habitats. They typically nest and roost in burrow systems created by medium-sized mammals (e.g., ground squirrels), artificial sites (e.g., drain pipes and culverts), or self-dug burrows where soil conditions are appropriate.

Approximately 600 pairs of burrowing owls are known to nest in the middle Central Valley, encompassing all of Yolo and Sacramento counties, most of Solano County, and other surrounding counties to the east and west, representing about 7% of the state breeding population (Center for Biological Diversity [CBD] et al. 2003). The pairs are associated largely with agricultural lands. Recent observations in Yolo County suggest that the population has declined by approximately 50% since 1985 to 30 or 40 pairs in 2000 (CBD et al. 2003). As of 2001, owls were known to occupy sites at UC Davis, the Yolo airport, and Mace Ranch Park (CBD et al. 2003). In Solano County, there have been numerous recent observations of breeding owls between the Yolo Bypass and Dixon, in the vicinity of Vacaville and Fairfield, and along the Delta (CBD et al. 2003). No nesting pairs are known to occur within the lower Putah Creek riparian corridor, but they could occur along edges of agricultural fields adjacent to lower Putah Creek. UC Davis is currently restoring habitat for burrowing owls at its Russell Ranch.

SWAINSON'S HAWK

Swainson's hawk is state listed as a Threatened species. This species prefers to nest in scattered tall riparian or woodland trees adjacent to grasslands and/or agricultural fields that provide suitable foraging habitat. Preferred foraging habitat includes agricultural fields planted with alfalfa, beet, tomato, or other low-growing row or field crops, fallow fields, dry-land and irrigated pasture, rice land (when not flooded), and cereal grain crops (including corn after harvest) (DFG 1994).

In 1989, it was estimated that approximately 80% of the total statewide population of 550 pairs was found in the Central Valley (DFG 1993). The dependence of Swainson's hawk on agriculture poses a continuing threat to a large percentage of the remaining population since current trends point toward cultivation of incompatible crop types such as vineyards, and conversion of agricultural lands to residential and commercial land uses (DFG 1993).

Swainson's hawks are known to nest along almost the entire length of lower Putah Creek, where there are suitable nest trees and foraging habitats (DFG 2003a). Based on long-term studies conducted within the 215 square mile area bounded on the south by the South Fork of Putah Creek, on the north by County Road 12 near Zamora, on the west by County Road 95, and on the east by the Yolo Bypass, there are an estimated 250 Swainson's hawk territories, of which about 130 are active in any given year (Estep 2003, unpublished data).

WHITE-TAILED KITE

The white-tailed kite is fully protected under §3511 of the California Fish and Game Code. Fully protected birds may not be "taken" or possessed at any time. "Take" is defined as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill. White-tailed kites are also protected under §3503.5 of the California Fish and Game Code, which prohibits the destruction of raptors and their nests. White-tailed kites prefer scattered trees for breeding and open grasslands and marshes for foraging. White-tailed kites typically nest in trees that are between 15 and 60 feet tall. Native tree species often used include oaks, cottonwood, and willows, but nonnative species such as eucalyptus and black walnut are also frequently used.

White-tailed kites nest along Putah Creek. Nests have been documented along lower Putah Creek near the UC Davis campus and in the Davis vicinity in strips of riparian and nonnative vegetation near agricultural fields (DFG 2003a).

YELLOW WARBLER

The yellow warbler is a California Species of Special Concern. Yellow warblers typically nest in willow thickets. Historically, yellow warblers were common nesters along the Sacramento River and tributaries throughout the Central Valley. By 1973, they were considered uncommon in this region, and recent studies have not detected yellow warblers breeding in riparian habitats on the valley floor, including locations where suitable habitat remains, such as the Cosumnes River Preserve in Sacramento County, Bobelaine Audubon Reserve in Sutter County, or in the Sacramento River National Wildlife Refuge (Heath 2001). Brood parasitism by the Brown-headed cowbird is believed to be largely responsible for nest failures of this species in riparian areas bounded by agricultural land uses.

Although yellow warblers are known to use the riparian woodlands along Putah Creek during migration, nesting has not been confirmed. However, a single male was observed singing from the confluence at Dry Creek into early July in 2003 and 2004 (Engilis, pers. comm. 2004). MAPS (Monitoring Avian Productivity and Survivorship) surveys initiated in 2005 will help establish the breeding status of this species on the creek.

YELLOW-BREASTED CHAT

Yellow-breasted chat is a California Species of Special Concern. Yellow-breasted chats typically nest in riparian habitats with a dense shrub layer. They tend to prefer willow, wild grape, and blackberry thickets (Ricketts et al. 2000). Historically, chats bred in suitable riparian habitat throughout the state, exclusive of higher mountains and coastal islands (Ricketts et al. 2000). By 1973, singing males were common on the Upper Sacramento River in northern Colusa County, but uncommon on the Feather River (Ricketts et al. 2000).

Recent surveys have detected chats breeding in very few locations in the Sacramento Valley, such as Clear Creek in Shasta County, Bidwell Park and Oroville Wildlife Area in Butte County and along Little Stony Creek in Colusa County (Ricketts et al. 2000). A few chats have been recently observed singing in the thick riparian growth on Putah Creek downstream from Monticello Dam (Kemper 2001) and near Pleasants Valley Road and Highway 128 (DFG 2003a).

Chats have been reported to use the introduced Himalayan blackberry in at least one area of California (Zack et al. 1997), and most likely use it throughout the state because of its dense thicket-forming properties (Ricketts et al. 2000). The Riparian Bird Conservation Plan recommends that any management efforts to remove this plant from riparian areas (i.e., invasive removal programs) should first assess any detrimental effects the removal may have on local breeding chats (Ricketts et al. 2000).

MODESTO SONG SPARROW

The Modesto song sparrow is being considered as an addition to the list of California Species of Special Concern. Several subspecies of song sparrows are known to breed in California.

Modesto song sparrows are year-round residents in the central lower basin of the Central Valley, from Colusa south to Stanislaus County and east of the Suisun marshes (Humple and Geupel 2000). The ecological requirements of the Modesto song sparrow are largely undescribed. What is known comes mainly from studies performed at the Cosumnes River Preserve in southern Sacramento County (Humple and Geupel 2004). Song sparrows prefer freshwater marshes and riparian willow thickets, especially areas with small clearings and early successional riparian vegetation (Grinnell and Miller 1944). Song sparrows also nest in riparian forests of valley oak (*Quercus lobata*) with a sufficient understory of blackberry (*Rubus* spp.), along vegetated irrigation canals and levees, and in recently planted valley oak restoration sites (DiGaudio and Geupel 1998, PRBO unpublished data).

Along the lower reaches of the Sacramento River, the Modesto song sparrow is notably absent from almost all riparian areas, based on recent breeding surveys (Humple and Geupel 2000). They are most numerous in the Delta and Butte Sink areas (Gardali 2001). In the northern San Joaquin Valley, they are locally numerous in several riparian corridors, such as the Cosumnes, Mokelumne, and Stanislaus rivers, and sparse along vegetated irrigation canals and levees (Gardali 2001).

Song sparrows were observed during resource assessment surveys in several locations along lower Putah Creek. In the foothill region, song sparrows are likely to be the Marin subspecies (*M. m. gouldii*), which ranges from the coast inland to western Yolo and Solano counties (Humple and Geupel 2000). Farther downstream toward the valley floor, it is likely that the song sparrows present are the Modesto subspecies. Modesto song sparrows are expected to nest in suitable habitat along the lower portions of Putah Creek.

6.5.2 SPECIAL-STATUS PLANTS

ROSE-MALLOW

Rose-mallow (*Hibiscus lasiocarpus*) is an emergent perennial herb in the mallow family (Malvaceae) that produces large white or pink flowers. This CNPS List 2 species blooms from June to September. CNPS List 2 plants are those that are considered rare, threatened, or endangered in California but are more common elsewhere (CNPS 2002). Suitable habitat consists of freshwater marshes and swamps. Rose-mallow could occur within patches of riverine wetland located in the creek channel, but it was not observed during summer 2002 surveys.

6.5.3 PROTECTION MEASURES

The USFWS, NMFS, and DFG have concurred that an initial set of restoration activities proposed as part of the Watershed Management Action Plan is unlikely to have an adverse affect on special-status species, so long as certain protection measures are implemented during restoration activities to ensure that impacts to these species are avoided or minimized. Protection measures required in conjunction with all proposed restoration activities are provided in Appendix I.

7

Invasive Weeds

7 INVASIVE WEEDS

This chapter provides an overview of invasive weeds issues, briefly describes invasive weeds present in the lower Putah Creek watershed, and describes the current distribution of invasive weed infestations in the lower Putah Creek riparian corridor from field surveys conducted in 2002. Introduced invasive fish and aquatic invertebrates are discussed in Chapter 5, "Fisheries," Section 5.2, "Introduced and Invasive Species."

The assessment will help to determine strategies to efficiently remove invasive weeds and provide maximum benefit to watershed resources. It also serves as a baseline from which to assess rates and patterns of weed growth and spread, and to determine the effectiveness of weed abatement projects over time. A Weed Abatement Plan (WAP) will be developed to provide guidance for the identification and control of invasive weeds in the watershed. The WAP will contain detailed information describing the ecology of each weed species, control and monitoring methods, and management practices.

7.1 DEFINITION AND OVERVIEW OF INVASIVE WEEDS

An invasive weed is a plant that has been introduced into a region where it is not native and has the potential to cause environmental or economic harm. Terms such as nonnative, non-indigenous, exotics, pest plants, and alien species are commonly used as synonyms for invasive weeds. Invasive weeds often have no natural enemies or competitors in their new environment, and they frequently have characteristics that allow them to out-compete other plants and grow and spread rapidly. Accordingly, invasive weeds can quickly proliferate and displace native plant populations and contribute to a loss of habitat to native wildlife dependent on those plants. Invasive weeds can also affect the balance of natural processes such as the frequency and extent of fires, flooding, sediment transport and deposition, erosion and channel formation, and nutrient cycling. Such alterations can contribute to further habitat loss and damage human infrastructure and land uses, causing economic hardship and safety concerns.

Disturbance is often a main trigger for the introduction and spread of invasive weeds. Undisturbed landscapes with established native vegetation are generally considered more resistant to weed invasion than disturbed landscapes. Invasive weed species are often able to colonize after some type of natural or manmade disturbance (e.g., fire, flood, gravel mining, and vegetation clearing) opens up areas and creates an opportunity for invasive weeds to establish. Human activities, including road building and maintenance, construction projects, heavy grazing, and the planting of exotic ornamental plants around buildings and parks, have all contributed to the widespread introduction of invasive weeds. Once introduced, invasive weeds can, and often do, spread into relatively pristine, or undisturbed, natural communities.

Many plants have been introduced to California and to the Central Valley region. Most are not considered invasive. Plants in the lower Putah Creek riparian corridor are considered invasive if they exhibit one or more of the following characteristics:

- *Invasive and habitat transforming* – Invasive and habitat-transforming species typically possess characteristics that allow them to out-compete other species and quickly dominate and transform a landscape. Often, weedy species have reproductive adaptations that allow them to rapidly spread and develop, or produce compounds that are released into the soil that inhibit the growth and survival of other species. They have typically developed these characteristics in their native habitat to compete with the species with which they have co-evolved. However, freed of the predation and competition from their native associates, they often have a competitive advantage over species in the environment in which they are introduced. Some examples of invasive and habitat-transforming species in the lower Putah Creek riparian corridor are Himalayan blackberry, perennial pepperweed, and arundo.

- *Threat to native species biodiversity* – Plants and animals have generally co-evolved over the millennia in association with other species native to their region, often resulting in highly interdependent biological networks. Many flora and fauna rely solely on a very small number of species for their survival. Invasive weed species are able to capitalize on the lack of predation in their new environments, free of biological predators that exist in their native environment. As a result of these and other characteristics that make them successful, they often out-compete native species and alter the composition and abundance of native plant species in the invaded plant community. This alteration of plant communities often results in the loss of habitat (food and shelter) for native wildlife dependent on native plants, leading to a decline in native wildlife species. The rapid extinction of species worldwide today is considered by many ecologists to be a result of habitat conversion, both direct (e.g., land use changes) and indirect (e.g., global warming), and the introduction of invasive weeds. Some examples of invasive species in the lower Putah Creek riparian corridor that alter plant communities and threaten native species biodiversity include eucalyptus and tree-of-heaven.

- *Threat to infrastructure* – Several invasive weed species pose a hazard to infrastructure features such as homes, roads, and bridges by increasing the frequency, intensity, and damage from natural processes. The timing or intensity of natural disturbance regimes such as fires, floods, and erosion can be altered by the presence of certain weed species resulting in costly losses of structures and increased maintenance to prevent those losses. Some examples of invasive species that threaten infrastructure in the lower Putah Creek riparian corridor include tamarisk, eucalyptus, and arundo.

- *Not naturalized* – Species that are not naturalized are still considered controllable. In contrast to these, several introduced species are now considered naturalized in California or a particular region within California, meaning they have largely colonized and/or transformed most areas in which they could grow. They are generally widely distributed, abundant, and stable in the landscape and are no longer considered containable. However, species that are not naturalized are still transforming the landscape and negatively affecting ecosystems. They have not yet reached the levels of abundance and distribution at which they are considered beyond control. All of the invasive species discussed in this chapter are generally considered controllable, either locally or regionally.

Following are examples of some of the concerns regarding invasive weeds in the lower Putah Creek watershed:

- *Biodiversity* – Tree of heaven, arundo (Exhibit 7-1a and 7-1b), eucalyptus, and perennial pepperweed are species that form large monocultures that exclude most other vegetation. They spread both by seed (except arundo) and vegetatively. The change in plant species composition and structure as a result of these invasive weeds reduces usage by most native wildlife.

- *Agriculture* – Yellow starthistle is a plant with a deep, vigorous tap root that rapidly depletes soil moisture following the end of the rainy season, providing it with a competitive advantage. It invades and dominates grassland, rangeland, and crop fields, creating a large problem for the agricultural community.

- *Fire* – Riparian areas dominated by native plants often act as a buffer or green line that hinders the spread of fires. However, arundo, tamarisk, eucalyptus and other fire-adapted invasive plants create an enormous biomass of volatile, oily, or dry fuel. A recent fire in the riparian corridor near the City of Winters destroyed over a mile of riparian forest (Exhibits 3-4 and 7-1b). According to the local fire captain, Scotty Dozier, in a letter to Team Arundo del Norte, arundo was primarily responsible for spreading the recent fire from the north bank across 100 feet of open water to ignite dry grass on the south bank where it burned an additional half-mile of riparian habitat before the blaze could be controlled. Arundo acts as a combustive agent during a wildfire, following which it regenerates and spreads quickly. Although invasive weeds like eucalyptus, arundo, and tamarisk quickly resprout after fires, many native riparian plants are killed (Exhibit 7-1b) or regrow more slowly than the invasive weeds. As an example, about 5 days after a recent fire, arundo was observed to have sprouted from among smoldering logs and had already grown 5 inches tall. Further observations 3 months later documented the presence of native species that were only beginning to grow while the arundo that had burned to the ground had already grown 8–10 feet tall. Repeated fires (five fires over the past 10 years) east of the PDD have helped transform the native riparian woodland community to a large monoculture of arundo. The conversion of native riparian woodland to an invasive weed-dominated, fire-prone plant community frequently displaces native wildlife habitat.

- *Fish Habitat* – In-channel colonization by arundo and tamarisk is causing sediment bars to stabilize rather than disperse, restricting the extent of salmonid and lamprey spawning habitat. Introductions of nonnative fish and aquatic organisms also affect native fish habitat, and are discussed in Chapter 5, "Fisheries."

Arundo (top left), tamarisk (top right) and eucalyptus (bottom) form monotypic stands that crowd out native riparian plants and degrade native wildlife and fish habitat quality. These invasive weeds produce massive amounts of dry or oily tinder that fuels wildfires. Tamarisk and arundo alter the stream sedimentation pattern and create flooding and erosion problems in many locations.

Source: EDAW 2003

Invasive Weed Issues

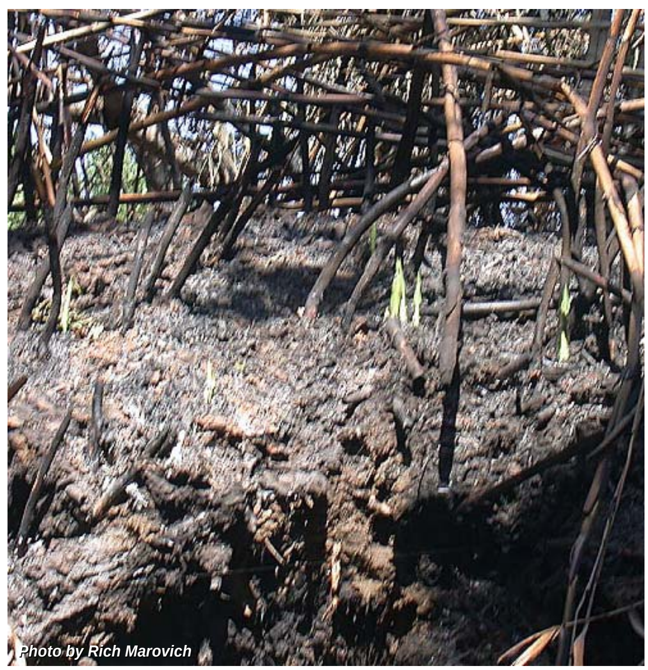
EXHIBIT 7-1a

EDAW

Equipment used to remove arundo along Pleasants Creek and Putah Creek. Arundo is ground to mulch and dried in place. The mulched stems can suppress weeds and reduce erosion in the transition period in which native plants are restored.

Pleasants Creek channel in 2002 following removal of arundo. Bank failure was thought to be caused, in large measure, by water forced into banks due to the arundo. Project funded by USFWS Partners for Wildlife grant.

A Winters area fire burned 1 mile of the riparian corridor in 2003, aided by dry arundo canes.



Arundo canes resprouting 5 days after the 2003 Winters area wildfire. Tinder was still smoldering.

Source: Rich Marovich, Jenny Drewitz, EDAW 2003

Invasive Weed Issues

EXHIBIT 7-1b

EDAW

- *Erosion and Bank Failure* – Heavy infestations of arundo have choked the channel along much of Pleasants Creek and Putah Creek (see Exhibits 4-2a and 7-1a/b), impeding flood flows. In Pleasants Creek and portions of Putah Creek, this has resulted in lateral erosion and failure of streambanks at the rate of 3 or more feet per year (Marovich pers. comm.), threatening structures and adjacent farmland and contributing to the failure of Pleasants Creek bridges. The sediment load from Pleasants Creek then moves downstream and accumulates in Lake Solano. Arundo and tamarisk also trap sediments during high flows, raising the elevation of gravel bars. The higher elevation cuts off floodplain access and constricts the channel. The constricted channel, in turn, causes higher flow velocities that can lead to accelerated erosion. Higher velocities can also lead to avulsion (sudden channel shifts) during high-flow events. For instance, at the confluence of Dry Creek and Putah Creek, a delta has formed from sediment transported primarily from Dry Creek. The deltaic gravel bar was colonized with Arundo that trapped sediment and stabilized the bar. As the gravel bar grew, it forced Putah Creek to avulse (i.e., jump out of its main channel) southward causing bank failure that may eventually destabilize Putah Creek Road.

7.2 METHODS

Invasive species were mapped and quantified through site surveys conducted during summer 2002 throughout the lower Putah Creek riparian corridor. Invasive weed surveys took place in two phases. The first phase was conducted in May and June 2002 as part of the biological resources assessment of four properties identified by the LPCCC for potential wildlife habitat enhancement and restoration activities (EDAW 2003). The second phase was conducted throughout the entire study area during summer 2002 in conjunction with plant and wildlife resource surveys described in Chapter 6, "Vegetation and Wildlife," Section 6.1, "Methods." Surveys were conducted from public roads and waterways, and from lands where access was granted by the landowners. Methods included walking the riparian corridor along one or both sides of the creek and surveying sections of the creek in a canoe. Each infestation (i.e., discrete patch [occurrence] of a particular weed) encountered along the survey route was mapped onto a laminated aerial photograph. Additional data were collected on infestations observed at 57 sampling locations as described in Chapter 6, "Vegetation and Wildlife," Section 6.1, "Methods." A copy of the data form is provided as Appendix C. Data collected included estimates of the size of infestations, quantity and sizes of invasive trees, percent cover of the weed in its canopy layer, position of the weed within the creek profile, erosion problems caused by the weed (if any), and quantity of recruits (e.g., seedlings) of the weed and other native and nonnative species in the infested area. All survey data and mapped infestations were entered into a GIS database. Some areas along Putah Creek and Pleasants Creek were inaccessible and infestations could only be mapped for one side of the creek. In addition, the view of portions of the riparian corridor was frequently obstructed by vegetation or topography. As a result, the true size and extent of some infestations are likely to be underestimated. For example, in one especially wide part of the channel where the only permissible access was from canoe, an infestation of Himalayan blackberry was estimated to be 0.25 acre. When land surveys were subsequently allowed by a new landowner, the same infestation turned out to be 16 acres of nearly solid thicket.

7.3 EXISTING CONDITIONS

A total of 21 plant species was identified as invasive weeds in the lower Putah Creek riparian corridor. These species are listed in Table 7-1, along with their status as a state-listed noxious weed, status as invasive by the California Invasive Plant Council (CalIPC), and their current or historic uses. About 75% of the invasive weeds in the lower Putah Creek watershed riparian corridor are of horticultural origin. All but one of the identified invasive weed species were mapped and assessed during surveys. Water hyacinth (*Eichhornia crassipes*) is an aquatic plant that was not found during the 2002 surveys, although it has previously infested Putah Creek. It likely died back during winter(s) and/or was displaced by high channel flows.

Table 7-1
Lower Putah Creek Watershed Invasive Weeds Status and Current or Historic Uses

Invasive Weed	State Noxious Weed (CDFA) [1]	CalIPC List (1999) [2]	General Habitats	Horticultural	Agricultural	Erosion Control	Wind Breaks	Other
Almond *Prunus dulcis (P. americana)*	--	--	streambanks, riparian forests		X			
Arundo *Arundo donax*	L	A-1	waterway edges, riparian communities	X		X	X	X
Black locust *Robinia pseudoacacia*	--	B	forests/woodland, fallow fields, roadsides, meadow edges, oak savannas, streambanks and ravines	X				
Catalpa *Catalpa bignonioides*	--	--	drainages, roadsides, riparian forests	X				
Edible fig *Ficus carica*	--	A-2	stream banks, levees, agricultural ditches, channel bottoms, riparian forests	X	X			
English ivy *Hedera helix*	--	B	forests/woodlands, forest edges, fallow fields, wetland edges, roadside and riparian corridors	X				
Eucalyptus, river red gum *Eucalyptus camaldulensis*	--	A-2	roadways, wind screens/shelterbelts, riparian forests, floodplains	X	X		X	
Eurasian watermilfoil; Parrot feather *Myriophyllum spicatum; Myriophyllum aquaticum*	--	B; A-1	Slow-moving water including streams, ditches, marshes, lakes, ponds, canals	X				X

Table 7-1 **Lower Putah Creek Watershed Invasive Weeds Status and Current or Historic Uses**								
Invasive Weed	State Noxious Weed (CDFA) [1]	CalIPC List (1999) [2]	General Habitats	Horticultural	Agricultural	Erosion Control	Wind Breaks	Other
Fennel *Foeniculum vulgare*	--	A-1	waste places, pastures, abandoned lots, wetland and stream edges, plowed or grazed areas		X			X
Himalayan blackberry *Rubus discolor*	--	A-1	disturbed landscapes, fallow fields, roadsides, pastures, forest plantations, right-of-ways	X	X			X
Jubata grass, pampas grass *Cortaderia jubata, C. selloana*	L	A-1	roadsides, cut banks, dunes, coastal bluffs, landslides, logged lands, stream corridors and open landscapes	X		X		
Milk thistle *Silybum marinum*	--	--	roadsides, pastures, waste places, river flats, areas with high soil nitrogen levels, ditches, other high disturbance areas					X
Pepper tree *Schinus molle*	--	B	washes, fallow fields, steep canyon slopes, streambanks, and roadsides	X				
Perennial pepperweed *Lepidium latifolium*	B	A-1	grassland, roadsides, disturbed sites, riparian areas, wetland and stream edges	X				X
Tamarisk, salt cedar *Tamarix ramosissima, T. parviflora*	L	A-1	riparian forests, floodplains, lake and stream edges, irrigation ditches	X			X	
Tree of heaven *Ailanthus altissima*	L	A-2	roadsides, riparian corridors	X				X
Tree tobacco *Nicotiana glauca*	--	NMI	waste places, open and disturbed sites	X				
Vinca, periwinkle *Vinca major*	--	B	moist sites in shaded places, especially along streams, commonly escapes landscape plantings, roadsides and waste places	X				

Table 7-1
Lower Putah Creek Watershed Invasive Weeds Status and Current or Historic Uses

Invasive Weed	State Noxious Weed (CDFA) [1]	CalIPC List (1999) [2]	General Habitats	Horticultural	Agricultural	Erosion Control	Wind Breaks	Other
Virginia creeper *Parthenocissus quinquefolia*	--	--	forest edges and openings, along fence rows and streambanks	X				
Water hyacinth *Eichhornia crassipes*	--	A-2	Slow-moving water including streams, ditches, marshes, lakes, ponds, canals	X				X
Yellow starthistle *Centaurea solstitialis*	C	A-1	roadsides, foothill savannah, fallow fields, pastures, disturbed woodland					X
Total (21 weeds)				16	2	3	3	8

[1] CalIPC List Definitions:
[from California Invasive Plant Council's (CalIPC) Exotic Pest Plants of Greatest Ecological Concern in California (CalEPPC 1999)]

List A: Most Invasive Wildland Pest Plants; documented as aggressive invaders that displace native species and disrupt natural habitats. Includes two sub-lists:

List A-1: Widespread pests that are invasive in more than three Jepson regions (Regions listed in the Jepson Manual of Higher Plants of California, Hickman Edition)

List A-2: Regional pests invasive in three or fewer Jepson regions.

List B: Wildland Pest Plants of Lesser Invasiveness; invasive pest plants that spread less rapidly and cause a lesser degree of habitat disruption; may be wide-spread or regional.

NMI = Need More Information

NL = Evaluated, Not Listed.

-- = no status indicated

[2] CDFA Designations:
[California Department of Food and Agriculture]

B - Eradication, containment, control, or other holding action at the discretion of the commissioner.

C - State-endorsed holding action and eradication only when found in a nursery; action to retard spread outside of nurseries at the discretion of the commissioner; reject only when found in a crop seed for planting or at the discretion of the commissioner

L - Listed 2003, C designation anticipated

-- = no status indicated

A description of invasive weed laws and regulations are provided in Chapter 11, "Recommendations."

7.3.1 INVASIVE WEED SPECIES DESCRIPTIONS

The section provides a brief description of the invasive weeds mapped in the lower Putah Creek watershed riparian corridor. Table 7-2 presents the distribution and abundance of the most common invasive weeds.

DOMESTIC ALMOND

Almond trees are a major agricultural species grown throughout California. The trees are native to the Middle East and were subsequently spread throughout the Mediterranean regions in northern Africa and southern Europe by Egyptians, Greeks, and Romans. The almond was introduced to California in the 1700s by the Spanish missionaries who settled the Mission at Santa Barbara. It was not until the mid-1800s that the tree was grown in larger quantities (Marks Fruit Crops 2002). Ground squirrels likely hasten the spread of domestic almond on Putah Creek.

ARUNDO

Arundo (aka, giant reed), is an herbaceous perennial plant resembling bamboo. It is believed that arundo is native to eastern Asia, but has been widely cultivated around the world. The date of its introduction to California is unknown. By the 1820s, however, abundant populations were harvested in southern California for roof thatching and feed (Bossard et al. 2000). Arundo is commonly cultivated to produce reeds for wind instruments, for misguided use as an erosion control agent, and as an ornamental. The plant reproduces through creeping rootstocks and rooting stem fragments. Arundo's aggressive nature allows it to thrive in all types of soils and under a broad range of ecological conditions. Dense forests of arundo, which out-compete native vegetation and eliminate wildlife habitat, can create fire hazards and threaten infrastructure during flood events (Bell 1998, Team Arundo del Norte 1995).

BLACK LOCUST

Black locust is a short-lived deciduous tree from the Appalachian Mountains and other localized regions of the eastern United States. It is believed that settlers may have introduced this species to California during the gold rush era, but no documentation has been found to support the assertion (Bossard et al. 2000). The species is known for its robust sprouting and root suckers, which lead to the formation of dense colonies (Plant Conservation Alliance 1998). Young trees have extremely rapid growth rates and can be distinguished from other species by pairs of thick thorns along stems. The tree is extremely shade intolerant and spreads outward from the center of the infestation. Even though trees produce numerous seeds, rarely are any seedlings produced (Conservation Commission of Missouri 2003). With its rapid spread and growth abilities, black locust poses a threat to native plant communities and biodiversity. The tree populations expand rapidly, shade out most native plants, and have little growth under their dense canopies (Plant Conservation Alliance 1998).

CATALPA

Calalpa (aka southern catalpa) is a fast-growing deciduous tree native to the southeastern United States. This hardy species has large, heart-shaped leaves whorled around the stem. The leaves may emit an unusual odor when crushed. The seed pods are one of its most recognizable features. From summer through early fall, the tree bears long, bean-like pods (Brenzel 1995, NRCS 2002). Southern catalpa can often be spotted growing in drainages, along roadsides and within riparian forests. The plant produces large amounts of seeds that can be distributed by water. The tree can resprout from its trunk when cut or injured, but does not have the ability to reproduce by vegetative means (NRCS 2002). The rapid growth and tendency to outcompete native riparian species can result in the loss of biodiversity and a reduction of wildlife habitat value.

EDIBLE FIG

Edible figs are small deciduous trees or shrubs commonly cultivated for their fruit. Records can be found from Mesopotamia (currently Iraq) going back 4,900 years. There are numerous cultivars of edible fig. Trees that bear only female flowers produce edible fruits, while another variety that bears both male and female flowers, called caprifigs, produces unpalatable fruits. Spanish missionaries introduced the fig tree to California in 1769, where it was dubbed the 'mission' fig (Bossard et al. 2000). The primary method of reproduction for figs is through the production of seeds but, like many riparian species, it can grow from stem fragments. Birds and other mammals often eat the fruits and disperse the seeds intact through their waste. Seed dispersal also occurs when streams and rainwater carry and break apart the fruit (Bossard et al. 2000). The species exhibits some invasive characteristics, such as crowding out native riparian species, but is typically less invasive than many of the other species mapped within the lower Putah Creek riparian corridor. Along portions of the San Joaquin River and other riparian environments, figs have produced large clonal stands, excluding all other vegetation.

ENGLISH IVY

English ivy is a common woody vine that is a highly valued ornamental. Settlers arriving from Europe introduced English ivy during early colonial times and its native range includes Europe, northern Africa, and western Asia (Plant Conservation Alliance 2000). The long-lived plants typically escape into natural settings from nearby urban settings. The plant can reproduce by rooting stems as well as by the production of berries that attract wildlife. Dispersal and germination of viable seed is often attributed to birds. Digestion of seed by bird species removes the seed's tough coat and is then eliminated and dispersed into new areas (Bossard et al. 2000). English ivy is capable of out-competing native species for light, moisture, and nutrients. It suppresses the growth of trees it covers, and adds weight to the limbs of trees, making them more susceptible to breakage during storms (Okerman 2000). English ivy provides ideal habitat for Norway rats in waterways. However, the large homogeneous stands formed by the plant are not considered to provide much native wildlife habitat value. The plant is also considered slightly toxic to humans and animals.

EUCALYPTUS

The majority of eucalyptus trees in the lower Putah Creek riparian corridor are river red gum (*Eucalyptus camaldulensis*). River red gum is a fast-growing tree that commonly grows to between 80 and 120 feet. It is an evergreen, hardwood tree that is native to Australia, primarily along river channels (Chippendale 1988). The bark exfoliates leaving stems and trunks that are mottled and multicolored (tan, white, or grayish). The bark is generally smooth except near the base of the trunk where it is often rough. Its blue-gray leaves are up to 10 inches long, lance-shaped, and straight or curved. Its flowers are creamy white or yellow, and its fruit is a pea-like capsule containing tiny (pepper grain sized) seeds. Red gum is often found growing in large monoculture stands with little or no understory vegetation. The tree propagates easily from seeds, and the roots are considered invasive (Arizona Board of Regents 2004). The leaves of red gum, like other Eucalyptus species, likely have toxic compounds that are released into the soil litter layer, inhibiting the growth of other species. Eucalyptus stands are typically extremely flammable and pose a great fire risk. Recent analyses of cut stumps on Putah Creek have shown that eucalyptus can grow up to 1.53 inches in diameter in a single year. Removal costs increase exponentially with size. Young trees up to 12 inches in diameter can be removed without specialized equipment. Removal of larger trees is a job for specialists. Removal of very large trees (e.g., over 36 inches in diameter) can cost thousands of dollars per tree. Due to self seeding, rapid growth rates, and exponential cost increase with size, eucalyptus control has the greatest time value of any weed on Putah Creek.

EURASIAN WATERMILFOIL, PARROTS FEATHER

Eurasian watermilfoil and parrots feather are invasive aquatic weeds. The native species, Siberian watermilfoil (*Myriophyllum sibericum*), closely resembles the nonnative Eurasian watermilfoil (*M. spicatum*). To distinguish the two species, DNA analysis or pigmentation tests are sometimes conducted. Based on their growth form and floristic characteristics, the plants found in lower Putah Creek appear to be Eurasian watermilfoil, not Siberian watermilfoil. Eurasian watermilfoil, as well as parrot's feather, are both submerged aquatic plants that form dense mats of vegetation within waterways. These aquatic plants often become established in waterways via the dumping of aquariums or escaping home water gardens. Eurasian watermilfoil is native in parts of Europe, Asia, North Africa, and Greenland. Research done by the Washington Department of Ecology found that the species may have been introduced into Chesapeake Bay by ship ballast waters during the 1880s. Parrot's feather is indigenous to the Amazon region of South America and was imported to the United States in the late 1800s for use in aquariums and water gardens (Bossard et al. 2000). Both Eurasian watermilfoil and parrot's feather rely upon vegetative reproduction for spreading and dispersal. While the Eurasian watermilfoil does produce viable seed, it is not thought that sexual reproduction is a major factor in the spread of this species (Washington Water Quality Program 2002). These two species choke out waterways, shade out native aquatic species, reduce wildlife habitat values, interfere with recreational opportunities (i.e., boating, fishing, and swimming), create stagnant water favorable to mosquito reproduction, and increase water temperatures (Washington Water Quality Program 2002, Bossard et al. 2000). Threats to infrastructure include increased flooding problems and obstruction of irrigation pumps and water intakes

(Bossard et al. 2000). Eurasian watermilfoil was the predominant aquatic invasive weed in lower Putah Creek during surveys, with parrot's feather observed only in the Yolo Bypass portion of the creek.

FENNEL

Fennel has been cultivated for centuries and is widely naturalized in temperate climates (Bean and Russo 1988). The perennial plant has fine, feathery leaves and its crushed stems and leaves emit a strong licorice scent (Bossard et al. 2000). Native to southern Europe and the Mediterranean region, fennel has been used as a common medicinal and culinary ingredient since Roman times. There is little information on the initial establishment of fennel in California, but it has been around for at least 120 years (Bossard et al. 2000). Reproduction occurs through seed production, crown sprouting, and root fragmentation. Dispersal of seed by water is a main source of new infestations, but other common means of dispersal include seed attachment to vehicles, machinery, animal fur, clothing, and agricultural produce (Bean and Russo 1988). Once established, fennel is a difficult weed to eradicate. In native plant communities, the plant may potentially alter community structure and species composition. Fennel tends to out-compete native plant species because of its rapid growth and aggressive reproductive abilities and may release compounds that inhibit the growth of other plants. If left unchecked, fennel is likely to develop impenetrable, homogeneous stands (Bossard et al. 2000).

HIMALAYAN BLACKBERRY

Himalayan blackberry is a robust, sprawling vine that has become naturalized in moist areas throughout the west. This species, which originates from Europe, was imported for cultivation in the late 1800s by Luther Burbank, who dubbed the species the Himalayan giant, assuming it originated on the Asian continent (Bossard et al. 2000). The majority of Himalayan blackberry reproduction is vegetative. The plant forms shoots along its root system and stems typically root where they touch the ground. Cut stems and fragmented roots can also form new plants that can reproduce and re-sprout vigorously. The rambling blackberry canes grow quickly and send out roots when in contact with the soil. Himalayan blackberry has been observed to be both beneficial and detrimental to wildlife. Birds and mammals feed on the delectable fruit and disperse the seeds. The fast-spreading dense thickets provide valuable nesting and foraging habitat for many songbird species (RHJV 2000). This may be especially valuable in areas that lack protection from predators, such as narrowed riparian corridors, or riparian habitat lacking thickets formed by native species such as California rose or native blackberry. However, Himalayan blackberry bramble also harbors rats that prey on riparian birds (Truan pers. comm.). Its rapid spread also leads to competition with native riparian plants on which wildlife depend. The impenetrable thickets of blackberry impede passage of larger mammals through the riparian corridor and restrict their access to water (U.S. Department of Agriculture 2002a). Himalayan blackberry is the dominant understory vegetation in many locations. It retains its leaves in the winter in contrast with most of the riparian forest. While the native deciduous forest offers little resistance to flood flows when dormant in the winter, Himalayan blackberry remains a dense thicket throughout the year (Exhibit 7-2). While native trees mostly tower over flood stage elevations and offer little resistance to flows, Himalayan blackberry grows at the same elevation as flood flows. Wherever Himalayan blackberry grows on the floor of the channel, it impedes drainage. Thick deposits of sediment can be found in Himalayan blackberry thickets where the velocity of flood flows was reduced to the point that flows could no longer transport sediment. In many reaches of Putah Creek, Himalayan blackberry constricts the low-flow channel with levees that are formed by sediment deposits. In the Putah Creek channel, Himalayan blackberry is second only to arundo in causing bank erosion by deflecting flood flows (Marovich, pers. comm.).

MILK THISTLE

Milk thistle is a biennial or annual herb with distinctive white mottling along the veins of its dark green leaves. The plant's thistle-like flowers, usually purple to pinkish in color, produce tufted seeds that are dispersed long distances by wind. A typical milk thistle plant can produce up to 5,000 seeds during its life cycle (Bean 1985, Hickman 1993, Washington State Noxious Weed Control Board 2002). The weed usually establishes in tall, thick patches that exclude the growth of other plant species either by shading or competition. Seeds do not tend to germinate in areas with a thick litter layer such as well-covered perennial grassland. Disturbances such as over-grazing and fire also drive the proliferation of milk thistle in large areas. The plant is also considered toxic to some livestock (Bean 1985). In Putah Creek, milk thistle occurs mostly on the upper edge of the riparian forest or on upper terraces in full sun.

JUBATA GRASS/PAMPAS GRASS

These two large ornamental grasses are perennial species with long, sharp leaves that arise from a dense tufted base. Jubata grass is generally shorter and wider than the more erect, cascading tufts of pampas grass. Both are native to South America; pampas grass comes from Argentina, Brazil, and Uruguay (Bossard et al. 2000). It is believed that jubata grass was introduced to California from cultivated specimens in France and Ireland and was recognized as a weed beginning in the 1960s when it was found invading logged lands in Humboldt County (Bossard et al. 2000). Pampas grass was first introduced to California from European sources by a nursery in Santa Barbara. The plant was sold as an ornamental for hedges or landscape plantings, and the Natural Resource Conservation Service formerly planted the species to supply forage on rangeland and prevent erosion (Bossard et al. 2000). Both species reproduce by wind dispersed seeds, as well as vegetatively by root fragments that can be dispersed by water (Bossard et al. 2000). In addition to crowding out native species, pampas grass increases the potential for wildfires because each year it develops a thick layer of dry leaves and flowering stalks (Bossard et al. 2000).

Eucalyptus stand by Yolo Housing site and annual growth ring (inset). Eucalyptus is extremely flammable, posing a great fire risk. Removal costs can be thousands of dollars per tree (e.g., over 36" diameter). With rapid growth rates of up to 3 inches in diameter per year and high, size-dependent costs for removal, rapid control of eucalyptus is a high priority.

Himalayan blackberry smothers the banks of Putah Creek. The dense vines and year-round leaves trap sediment and impede flows. Recruitment of new native vegetation is hindered, resulting in loss of high quality wildlife habitat.

Source: Marovich 2005

Invasive Weeds: Eucalyptus and Himalayan Blackberry

EXHIBIT 7-2

PEPPER TREE

Pepper tree (aka California pepper tree) is a small to medium-sized shrubby evergreen tree native to the Andes region of Peru. The tree is willowy in appearance with long drooping upper branches. During the fall, reddish, peppercorn-like berries become apparent (Hickman 1993, Brenzel 1995). The seeds are often eaten and dispersed by birds (Brenzel 1995). Spanish missionaries most likely introduced the tree in 1830, but it has been used medicinally for centuries in South and Central America (Davidson 1936, Jōker et al. 2002). Pepper tree is an escaped ornamental weed and the resilient characteristics of this tree (i.e., its drought tolerance and rapid growth pattern) that make it a desired ornamental allow it to out-compete native vegetation. The tree is reported to cause hay fever, asthma, and dermatitis (De Ruff 2002). Pepper tree on Putah Creek currently occurs as widely dispersed solitary trees.

PERENNIAL PEPPERWEED

Perennial pepperweed is a very invasive weed of moist agricultural and wildland areas. It originates from southeastern Europe and southwestern Asia. The herbaceous perennial plant produces dense white flower heads and has alternately arranged leaves that clasp the stem. It is thought that perennial pepperweed was introduced to the United States in contaminated sugar beet seed, but the assertion may be undocumented. The first confirmed record of the plant was collected in 1936 on a ranch in Stanislaus County (Bossard et al. 2000). The primary methods of reproduction are from creeping roots and root fragments that produce new shoots and from numerous small seeds. The small seeds are commonly dispersed by water, wind, waterfowl (Bossard et al. 2000), and large equipment used for farming, ranching, and road maintenance (CDFA 2002). Perennial pepperweed's aggressive spreading capability typically leads to the formation of large, dense homogenous colonies over time. With the exclusion of native plant species, especially in wetland and riparian areas, wildlife habitat may be compromised. The sparsely branched root system, which readily fragments, tends to increase the erosion potential for streambanks during large flow events. Additionally, perennial pepperweed absorbs salt deep within the soil profile and transports it into its leaves where it is eventually deposited onto the soil surface. This alteration of soil chemistry may lead to the displacement of native plant species (Renz 2000).

TAMARISK

Tamarisk (aka salt cedar) is a deciduous shrub from southern Europe and Asia (Carpenter 1988). The origin of introduction for this plant has not been clearly determined, although many infestations are believed to have begun as intentional plantings for erosion control. Tamarisk disperses both by seed and vegetatively. Its numerous flowers can each produce thousands of tiny, tufted seeds dispersed by wind and water (Plant Conservation Alliance 1997). Vegetative reproduction occurs through submerged and rooting stems (Plant Conservation Alliance 1997). Tamarisk transforms the landscape and alters riparian systems in many ways. It draws salts from deeper soil layers and deposits them on the soil surface as it grows. The altered soil chemistry hinders the germination of native salt-intolerant riparian plants. Tamarisk colonizes and transforms floodplains and sediment bars by trapping sediment and altering the channel profile.

The species is highly adapted to fire and flooding and resprouts vigorously after these events. Eventually, tamarisk transforms the riparian landscape such that tamarisk-dominated areas have higher frequencies and intensities of fire and floods (Plant Conservation Alliance 1997). It also results in reduced wildlife habitat value to species dependent on the native trees and shrubs that tamarisk displaces. Tamarisk, like arundo and Himalayan blackberry, impedes flood flows as evidenced by a build up of sediment around the base of individual plants, occasionally causing bank erosion when it occurs in dense thickets.

TREE-OF-HEAVEN

Tree-of-heaven is a medium-sized deciduous tree with long divided (i.e., compound) leaves similar to black walnut, for which it is often mistaken. However, unlike black walnut, tree-of-heaven leaves omit a characteristically unpleasant odor when crushed. Tree-of-heaven is native to eastern China and was planted as a street tree throughout Europe and the United States during the 1800s by Chinese laborers as symbols for good luck (Bossard et al. 2000).
In California, it was widely planted until the late 1800s. The tree produces copious wind-dispersed seeds in late summer to early fall that resemble the winged seeds of maple. It spreads both by seeds and vegetatively from root sprouts and is common in disturbed urban or developed areas, as well as riparian areas. It is no longer popular as an ornamental because of its unpleasant odor and prolific root sprouting, which causes damage to pavement and structures in urban areas. Over time, dense thickets of young tree-of-heaven trees form, often around older established trees, creating monoculture stands that diminish wildlife habitat value.

TREE TOBACCO

Tree tobacco is a widely cultivated ornamental deciduous shrub from South America. It has bluish green leaves and shiny reddish brown fruits that appear in late fall and winter (Brenzel 1995, Hickman 1993, Wilken and Hannah 1998). Tree tobacco commonly infests waste places and open, disturbed sites. It has also been found to colonize freshly burned areas in southern California chaparral (Wilken and Hannah 1998). Tree tobacco can reproduce both sexually and asexually: its flowers are capable of self-fertilizing, but they are also pollinated by birds in naturalized habitats. The seeds germinate rapidly after dispersal, especially in open sites free from competition (Wilken and Hannah 1998). Tree tobacco appears to be increasing rapidly on Putah Creek, especially at burned sites. Its successful invasion of disturbed stream banks may be an impediment to the natural restoration of some stream bank areas by native riparian species.

VINCA

Vinca (aka periwinkle) is a sprawling mat-like vine native to southern Europe and northern Africa. It was introduced to many continents as a medicinal herb and later as an ornamental ground cover. Vinca creates dense vegetative carpets that preclude the growth of native species and, once established, are rather stable in natural environments (Bean and Russo 1988). It has been noted that the plant can affect hydrology within streams by inhibiting natural erosional processes and initiating channel incision (Bossard et al. 2000). Vinca often disperses from established plantings around residences (Bean and Russo 1988). The plant spreads mainly by vegetative growth, and it is not known to reproduce sexually in California. The arching stems that grow laterally can root at the stem tips, helping to create a thick mat. For long distance dispersal, water sometimes transports stem fragments within riparian zones that resprout and spread rapidly (Bossard et al. 2000).

VIRGINIA CREEPER

Virginia creeper is an ornamental woody vine known for its magnificent fall foliage that turns fiery orange to scarlet. The species is widely cultivated and native to the eastern and central United States. This fast-growing perennial attaches itself to upright surfaces by adhesive disks. Ripened bluish black berries, which are savored by many birds and mammals, are produced from August through October (Brenzel 1995, U.S. Department of Agriculture 2002b). The vine can also sprout from above ground, laterally growing stems as well as from the root crown (U.S. Department of Agriculture 2002b). Virginia creeper has the tendency to move out of landscaped areas to potentially smother and displace native vegetation.

WATER HYACINTH

Water hyacinth is a free-floating aquatic plant from the Amazon River basin and Pantanal region of western Brazil. Its thick, waxy green leaves are held upright above the water surface on bulbous, air-filled stalks. In early spring, the plants begin to vegetatively produce daughter plants by runners that grow horizontally and can produce new plants every 6 to 18 days (Western Aquatic Plant Management Society 2002). It is thought that the initial introduction to the United States occurred in 1884 when a visitor to the 1884–1885 World's Industrial and Cotton Centennial Exposition carried the plant to Florida where it spread to the St. John's River (Western Aquatic Plant Management Society 2002). By 1904, it had appeared in California (Bossard et al. 2000). It is a popular nursery item for home water gardens and ponds because of its showy flowers and ability to take up excess nutrients. Water hyacinth is considered one of the most productive plants on earth. By clogging waterways and displacing native aquatic species, the weed disrupts many natural settings and causes serious economic hardships. Many infestations are the result of deliberate introduction or the disposal of excess plants from someone's water garden (Bossard et al. 2000).

YELLOW STARTHISTLE

Yellow starthistle is an annual, sometimes biennial, herb that thrives in open, disturbed landscapes. Originating from southern Europe, the plant has spread to most temperate areas around the globe. It was probably first introduced to California during the Gold Rush as a seed contaminant in Chilean-grown alfalfa seed (Gerlach et al. 1998), and in the early 1900s as a seed contaminant in alfalfa seed from Europe. It has rapidly spread throughout California as an unintentional byproduct of alfalfa farming, feed, ranching, suburban development, and road building (Gerlach 1997a, 1997b; Maddox and Mayfield 1985; DiTomaso 2001). It is now estimated to infest 15–20 million acres in California and an additional couple of million acres in other western states (DiTomaso 2001). The plant spreads by seed, and its high germination rate and deep, vigorous tap root, which rapidly depletes soil moisture following the end of the rainy season, provide the competitive edge for yellow starthistle to displace native plants.

Yellow starthistle is also poisonous to horses, causing a nerve disorder called "chewing disease" (*nigropallidal encephalomalacia*), which is fatal once symptoms develop (DiTomaso et al. 2003). The loss of native vegetation and infestations within crop and grazing lands caused by this weed create a large problem for the conservation and agricultural communities. Creeping wild rye and Santa Barbara sedge, two perennial grasses that are native to Putah Creek, compete well with yellow star thistle and other herbaceous weeds.

7.3.2 INVASIVE WEED DISTRIBUTION AND EXTENT

This section summarizes weed distribution in the lower Putah Creek riparian corridor, followed by subsections discussing the distributions by reach and by individual weed species. There is also a comparison of the current distribution of weeds with the distribution of four invasive weeds indicated in the 1992 resource assessment maps produced by the USFWS (1993), to determine if and how those four invasive weeds may be spreading.

Invasive weed infestations cover over 127 acres, or about 6% of the lower Putah Creek riparian corridor. The invasive weeds vary greatly in their distributions; however, one or more invasive weeds are found throughout most of the approximately 1,900-acre riparian corridor. The distribution and extent of invasive weeds in the lower Putah Creek riparian corridor are summarized in Table 7-2 and Exhibits 7-3 and 7-4a–g. The most abundant weed species within the riparian corridor are arundo, eucalyptus, Himalayan blackberry, Eurasian watermilfoil, perennial pepperweed, tamarisk, tree-of-heaven, and yellow starthistle. These weed species each infests between 5 and 25 acres. Eucalyptus is the most extensive, with 302 infestations covering a total of 24 acres. Arundo exhibits the largest number of total infestations, with 406 infestations covering a total of 21 acres. Twelve of the weeds have total infestations amounting to less than 1 acre each. They include almond, black locust, catalpa, edible fig, English ivy, fennel, milk thistle, jubata or Pampas grass, pepper tree, tree tobacco, vinca, and Virginia creeper. They may be recent introductions to the watershed that have not yet dispersed extensively, or they may be contained to relatively few small areas thus far.

REACH DISTRIBUTION ANALYSIS

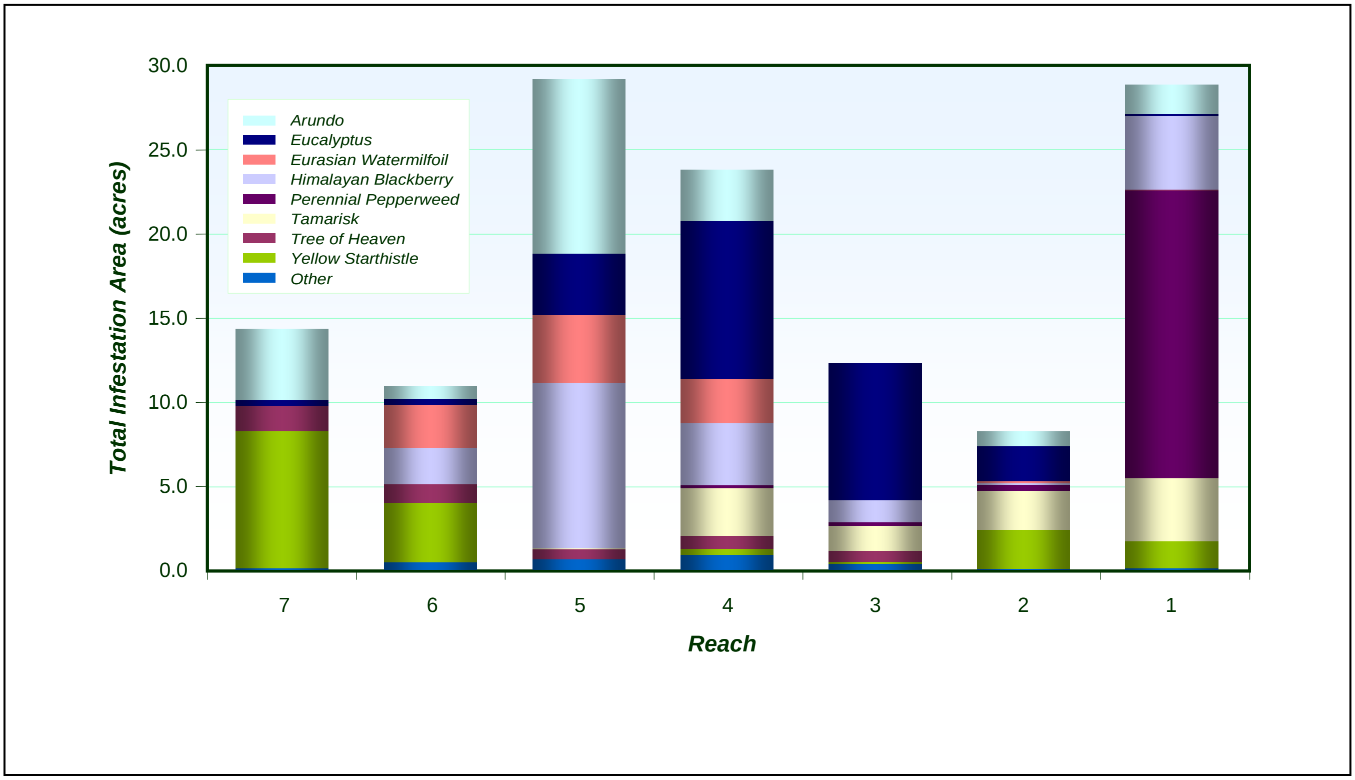
Beginning with the upstream reaches, seven weed species were mapped along Pleasants Creek (Reach 7), totaling over 14 acres in infestations (Exhibit 7-4a). Yellow starthistle and arundo are substantially more extensive in acreage than any other weeds in that reach. Tree-of-heaven is also moderately extensive and widely distributed. Based on the survey, the remaining four weeds, black locust, fig, eucalyptus, and pepper tree, together have infestations that amount to less than 0.5 acre.

In Reach 6, the interdam reach, thirteen invasive weeds were mapped, with infestations totaling over 11 acres (Exhibit 7-4b). The most abundant invasive weeds are yellow starthistle, Eurasian watermilfoil, Himalayan blackberry, tree-of-heaven, and arundo. The remaining eight weeds have infestations that total less than 1 acre together. They include black locust, fig, eucalyptus, fennel, jubata or Pampas grass, perennial pepperweed, tree tobacco, and vinca.

Table 7-2
Distribution of Invasive Weeds by Reach

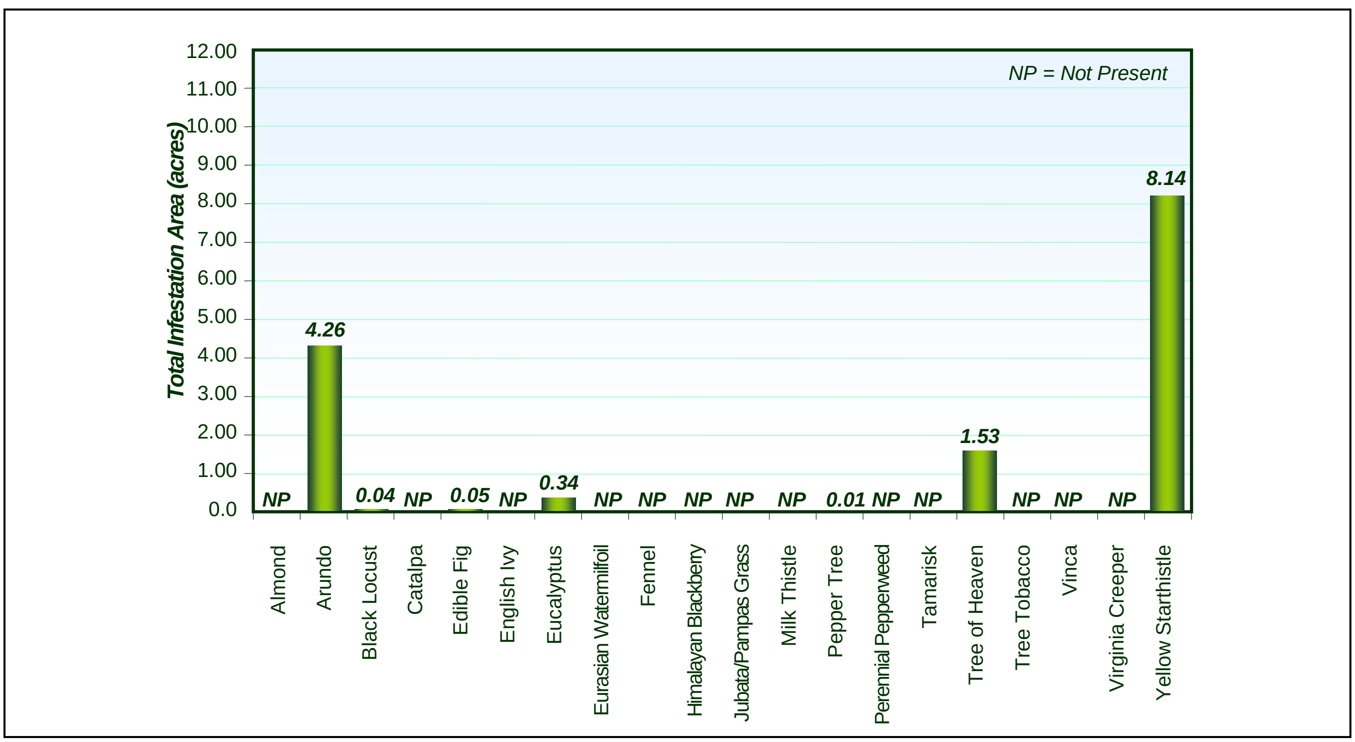
Weed	Reach 1 (Mace Blvd to Yolo Bypass)		Reach 2 (I-80 to Mace Blvd)		Reach 3 (Stevensons to I-80)		Reach 4 (I-505 to Stevensons)		Reach 5 (PDD* to I-505)		Reach 6 (Monticello to PDD*)		Reach 7 (Pleasants Creek)		Total Inf [1]	Total Acres	Avg. Inf Size (acres)
	Inf [1]	Acres	Inf [1]	Acres	Inf [1]	Acres	Inf [1]	Acres	Inf [1]	Acres	Inf [1]	Acres	Inf [1]	Acres			
Almond	--	--	--	--	--	--	5	0.12	21	0.23	--	--	--	--	26	0.3	0.01
Arundo	25	1.77	19	0.88	3	0.05	99	3.09	178	10.4	19	0.76	63	4.26	406	21	0.05
Black locust	--	--	--	--	4	0.32	2	0.07	5	0.07	2	0.04	3	0.04	16	0.5	0.03
Catalpa	--	--	--	--	--	--	5	0.01	1	0.01	--	--	--	--	6	0.02	0.003
Edible fig	--	--	1	0.01	3	0.02	9	0.05	22	0.18	15	0.17	5	0.05	55	0.5	0.01
English ivy	--	--	--	--	--	--	--	--	1	0.004	--	--	--	--	1	0.004	0.004
Eucalyptus	3	0.11	80	2.09	90	8.18	106	9.45	17	3.66	4	0.41	2	0.34	302	24	0.1
Eurasian watermilfoil; parrot's feather[2]	12	0.012	1	0.11	--	--	15	2.60	16	4.00	6	2.55	--	--	39	9	0.2
Fennel	--	--	--	--	--	--	--	--	--	--	9	0.09	--	--	9	0.09	0.01
Himalayan blackberry	36	4.36	3	0.09	34	1.30	51	3.72	89	9.96	28	2.21	--	--	241	22	0.1
Jubata grass; Pampas grass	--	--	--	--	--	--	--	--	--	--	1	0.04	--	--	1	0.04	0.04
Milk thistle	2	0.08	--	--	--	--	6	0.66	--	--	--	--	--	--	8	0.7	0.1
Pepper tree	--	--	--	--	--	--	--	--	8	0.09	--	--	2	0.01	10	0.1	0.01
Perennial pepperweed	104	17.22	14	0.36	10	0.22	14	0.20	--	--	1	0.01	--	--	143	18	0.1
Tamarisk	109	3.75	88	2.35	72	1.48	118	2.84	6	0.06	--	--	--	--	393	10	0.03
Tree-of-heaven	3	0.04	2	0.01	8	0.65	22	0.76	27	0.58	17	1.13	44	1.53	123	5	0.04
Tree tobacco	--	--	6	0.04	3	0.02	--	--	1	0.01	21	0.10	--	--	31	0.2	0.01
Vinca	--	--	--	--	--	--	--	--	--	--	1	0.004	--	--	1	0.004	0.004
Virginia creeper	--	--	1	0.03	--	--	--	--	3	0.03	--	--	--	--	4	0.06	0.02
Yellow starthistle	2	1.61	4	2.27	3	0.10	4	0.34	--	--	7	3.51	8	8.14	28	16	0.6
Total	285	28.95	219	8.24	230	12.34	456	23.91	395	29.25	131	11.02	127	14.37	1843	127.52	

Notes:
[1] Inf = Number of infestations
[2] Parrot's feather was found only in Reach 1
"--" = no infestations observed
*PDD = Putah Diversion Dam



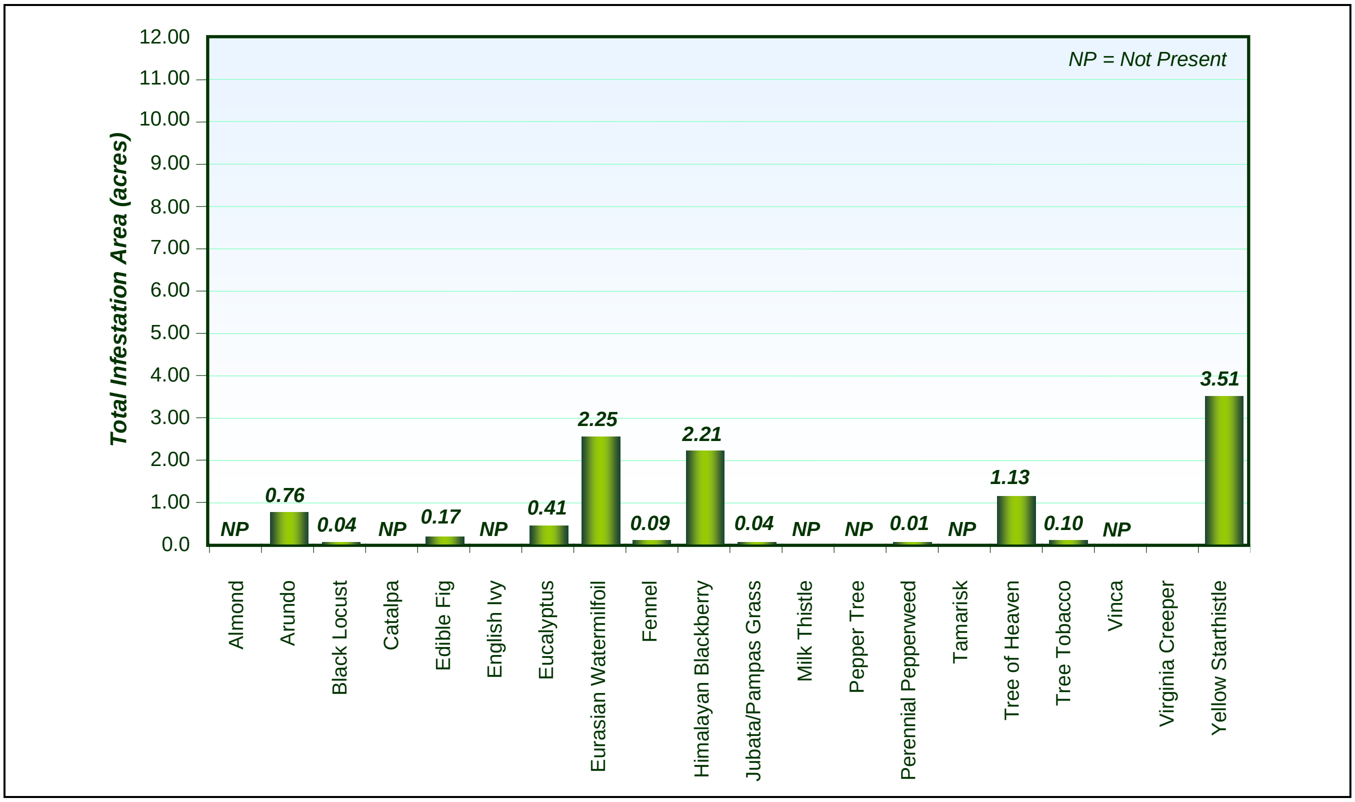
Distribution of Invasive Weeds by Reach

EXHIBIT 7-3



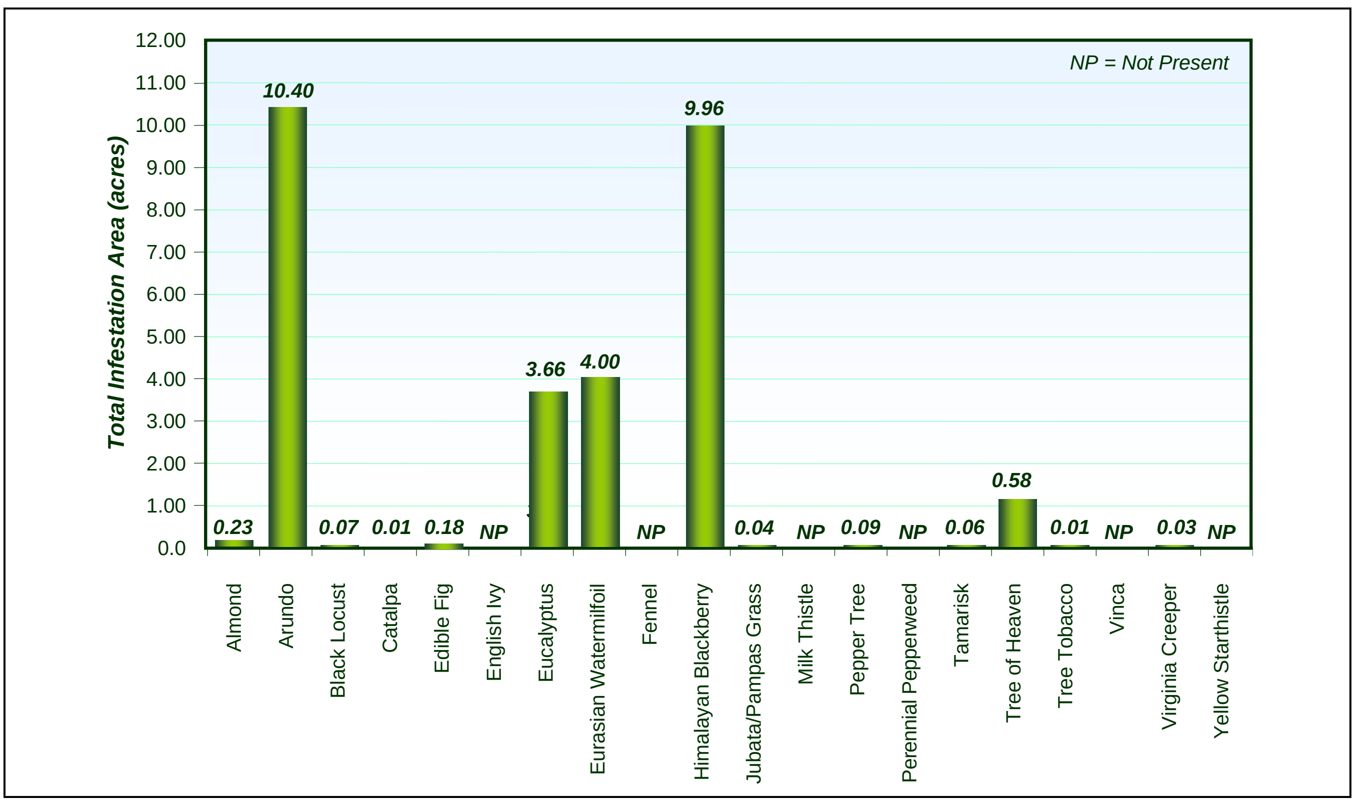
Distribution of Invasive Weeds by Reach 7, Pleasants Creek

EXHIBIT 7-4a



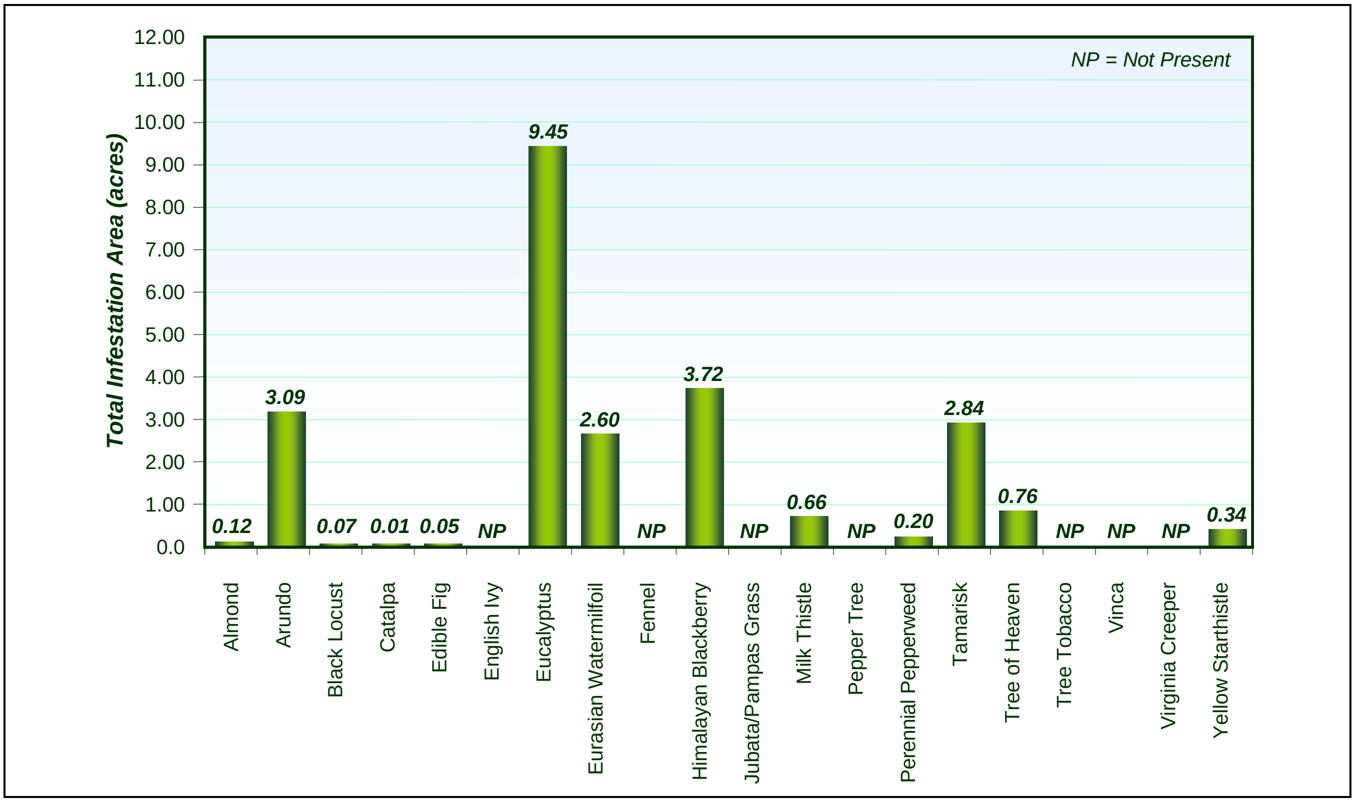
Distribution of Invasive Weeds in Reach 6,
Monticello Dam to Putah Diversion Dam

EXHIBIT 7-4b



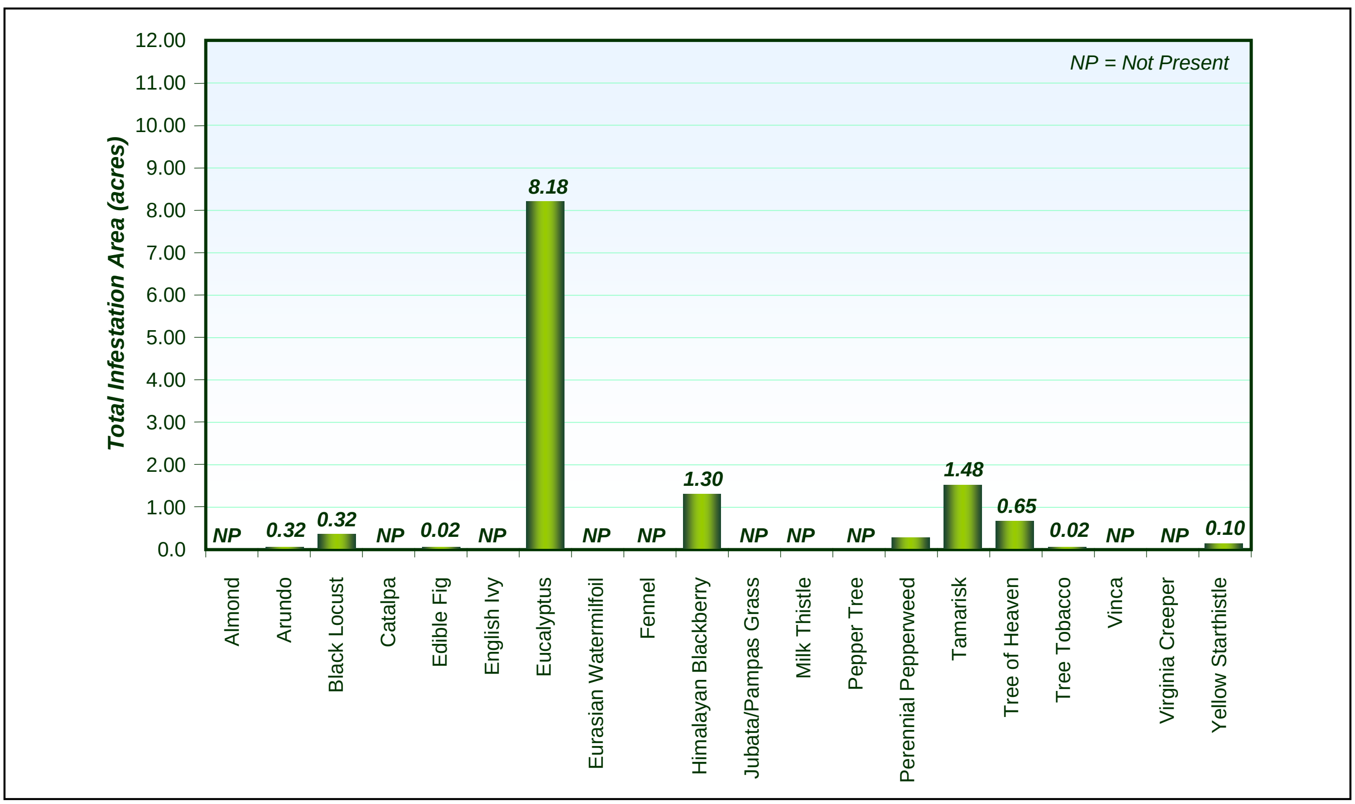
Distribution of Invasive Weeds in Reach 5,
Putah Diversion Dam to I-505

EXHIBIT 7-4c



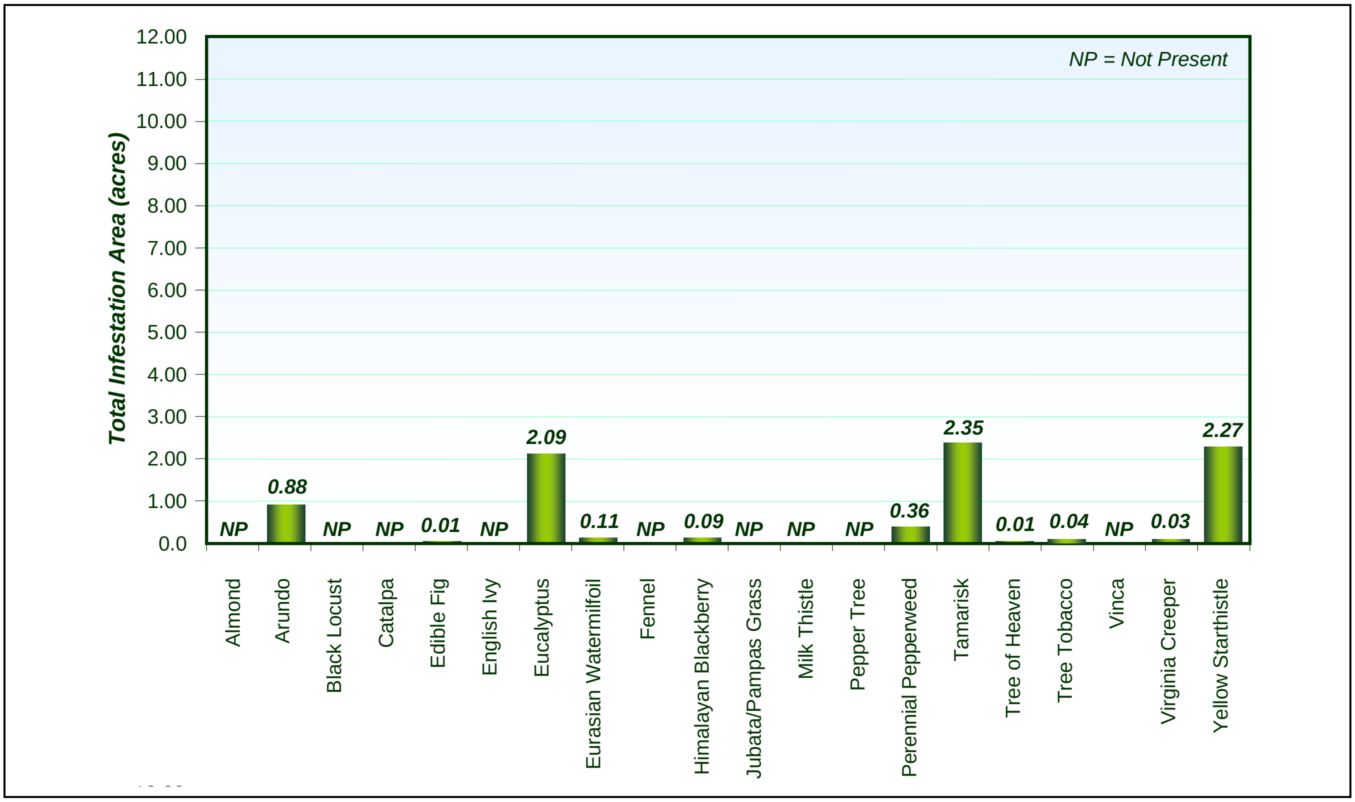
Distribution of Invasive Weeds in Reach 4,
I-505 to Stevensons Bridge

EXHIBIT 7-4d



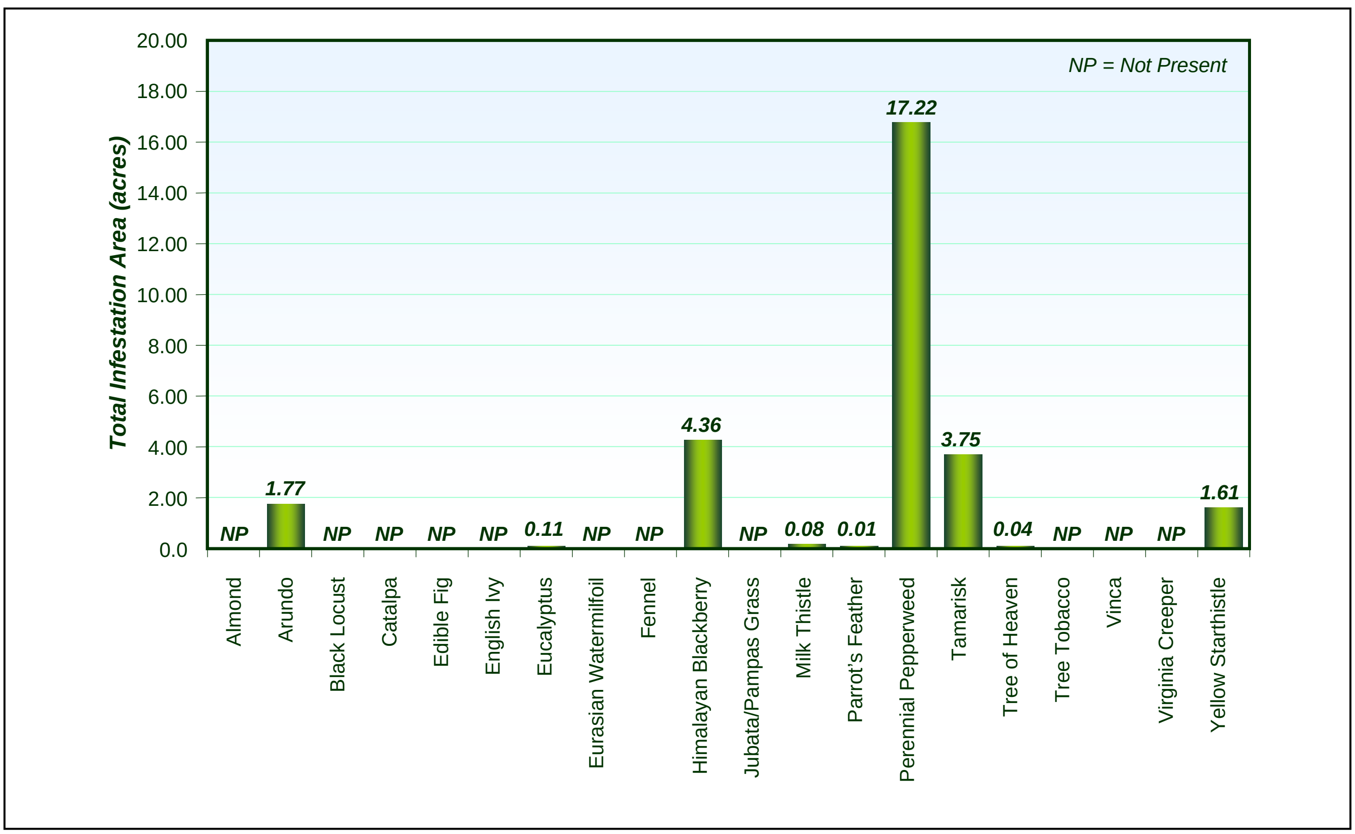
Distribution of Invasive Weeds in Reach 3
Stevensons Bridge to I-80

EXHIBIT 7-4e



Distribution of Invasive Weeds in Reach 2,
I-80 to Mace Blvd.

EXHIBIT 7-4f



Distribution of Invasive Weeds in Reach 1,
Mace Blvd to Yolo Bypass

EXHIBIT 7-4g

In Reach 5, the area from the PDD to I-505 near Winters, fourteen invasive weed species were mapped, more than in any other reach (Exhibit 7-4c). The infestations of those weeds total over 29 acres, which is more extensive than in any other reach, except Reach 1, which has nearly the same total infestation area. However, unlike Reach 1, there are several weeds in Reach 5 that account for the infestations. Only Reach 4 has more infestations than Reach 5. Arundo and Himalayan blackberry infestations in Reach 5 are substantially larger in total acreage than in any other reaches in the study area, with each of those weeds totaling about 10 acres. That represents about half of the total infestation areas along lower Putah Creek for those two weeds. Eurasian watermilfoil, at 4 acres, is also much more extensive in Reach 5 than in any other reach. Eucalyptus begins to become a dominant species in the landscape in Reach 5, increasing in number of infestations and total acres in Reaches 4 and 3 before tapering off in Reach 2. A total of 10 additional invasive weeds occur in Reach 5, amounting to just over 1 acre of infestations together. These include almond, black locust, catalpa, fig, English ivy, pepper tree, tamarisk, tree-of-heaven, tree tobacco, and Virginia creeper. The high number of horticultural weeds found in this reach may be associated with landscaping around residences and commercial developments or parks near or in the City of Winters.

In Reach 4, from I-505 at Winters to Stevensons Bridge midway between Winters and UC Davis, thirteen weed species were documented, with infestations from these weeds totaling nearly 24 acres (Exhibit 7-4d). Eucalyptus is more extensive in this reach than in any other reach in the study area. Tamarisk is also abundant in this reach, unlike any reaches upstream of this point in the study area, suggesting that the source populations may have begun in this reach. Arundo, Himalayan blackberry, and Eurasian watermilfoil are all extensive in this reach, although not as abundant as they are in Reach 5. Due to the high number of infestations of arundo, eucalyptus, Himalayan blackberry, and tamarisk, Reach 4 has the highest number of infestations along lower Putah Creek. The remaining eight weeds occurring in this reach total just over 2 acres, with most of that acreage accounted for by infestations of tree-of-heaven and milk thistle. The remaining six weeds include almond, black locust, catalpa, edible fig, perennial pepperweed, and yellow starthistle.

In Reach 3, from Stevensons Bridge to I-80 near the UC Davis Putah Creek Riparian Reserve, 10 invasive weed species were mapped with a total infestation area of just over 12 acres (Exhibit 7-4e). Eucalyptus, at over 8 total acres, is by far the most dominant weed in this reach. Tamarisk and Himalayan blackberry are also somewhat extensive, with each totaling over an acre. However, they are not as abundant as they are in Reach 4, immediately upstream. The remaining seven weeds account for about 1.3 acres, primarily because of tree-of-heaven infestations. The remaining weeds include arundo, black locust, edible fig, perennial pepperweed, tree-of-heaven, tree tobacco, and yellow starthistle.

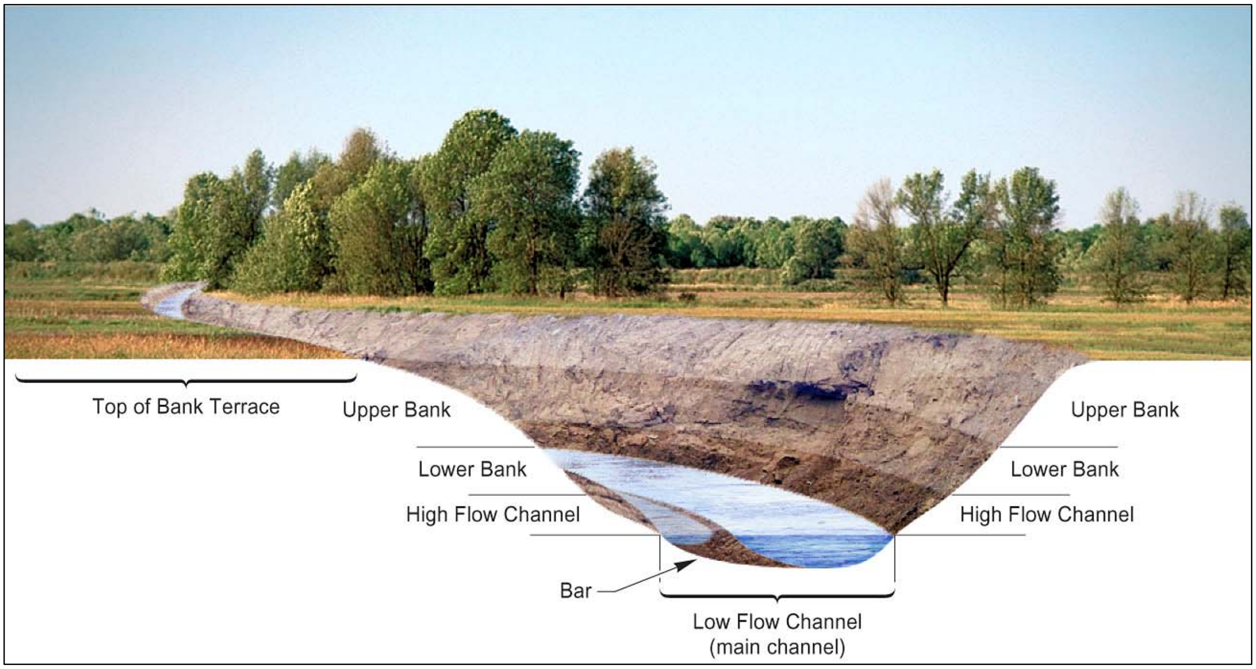
In Reach 2, from I-80 to Mace Boulevard south of Davis, eleven weed species were mapped, with infestations totaling about 8 acres (Exhibit 7-4f). Reach 2 is one of the least infested reaches in the study area. However, there is a moderate infestation of yellow starthistle, and the extent of tamarisk in this reach is second only to Reach 1, downstream. The eucalyptus infestation area is still substantial in this reach, but much less than it is in the next three reaches upstream. Arundo accounts for about an acre. The remaining seven weeds in this reach account for less than an acre of infestations. They include edible fig, Himalayan blackberry, Eurasian watermilfoil, perennial pepperweed, tree-of-heaven, tree tobacco, and Virginia creeper.

In Reach 1, from Mace Boulevard to Putah Creek's confluence with the Yolo Bypass, nine invasive weed species were mapped, accounting for nearly 29 acres of infestations (Exhibit 7-4g). Reach 1 and Reach 5 have the largest total infested area by reach. In Reach 1, the infestations are primarily due to an abundance of perennial pepperweed. Perennial pepperweed, at over 17 acres, is by far the most dominant weed in this reach, and it accounts for almost all of the pepperweed found along lower Putah Creek. The tamarisk population is also larger in this reach than in any other. Additional weeds with sizable populations include Himalayan blackberry, arundo, and yellow starthistle. Only four other weeds were mapped in Reach 1, and they account for only about 0.2 acre of infestations. The four weeds are eucalyptus, milk thistle, Eurasian watermilfoil, and tree-of-heaven.

Individual Species Distribution Analysis

The following discussion characterizes the distribution of individual invasive weed species growing in the lower Putah Creek riparian corridor. The discussion describes the general location where the weed grows within the stream channel profile, shown in Exhibit 7-5, and a designation as one of three distribution profiles. The channel was partitioned into the low-flow channel, sediment bars within the low-flow channel, the high-flow channel, lower and upper banks, and the top of bank terrace for purposes of weed data collection. Invasive weeds in the riparian corridor are assigned to one of three distribution profiles that characterize the extensiveness of each weed in the watershed. The distribution profiles are described in Table 7-3. The distribution profiles are defined based on relative differences in the number of infestations and the average size of each infestation. They will help determine priorities for future abatement actions. The types range from weeds presumed to have recently invaded and/or which have not yet spread throughout the corridor to those which are now ubiquitous in the corridor. The acreage and infestation frequency values provided to define differences between groups are based on approximate ranges of values in which the invasive weeds appear scarce, widespread, or ubiquitous in the lower Putah Creek riparian corridor. The distribution characteristics of each invasive weed species are summarized, along with the distribution profile designation, in Table 7-4.

There are twelve invasive weeds in the lower Putah Creek riparian corridor that can be considered incipient. They have characteristically small and relatively confined infestations that have not yet spread extensively throughout the corridor. They are indicated in Table 7-4. Together, infestations of the twelve incipient weeds currently account for only 2.5 acres, or 2% of all mapped infestations in the riparian corridor. Three weeds, including arundo, tamarisk, and tree-of-heaven, are considered widespread with numerous small infestations throughout much of the riparian corridor. These weeds have characteristics of having recently spread and colonized in much of the corridor, but the infestations have not yet grown to a large size. Unabated, they are likely to quickly become more extensive in size. The three widespread



Creek Channel Profile

EXHIBIT 7-5

Table 7-3 Distribution Profile Characteristics of Lower Putah Creek Riparian Corridor Invasive Weeds				
Distribution Profile	Average Size of Each Infestation 1 (acres)	Total Number of Infestations	Total Infestation Area 2	Comments
Incipient – Few Small Infestations (I)	Small – less than 0.1 acre	Less than 100	Small – less than 1 acre	Presumed to be very recent introductions or those relatively contained thus far
Widespread – Many Small Infestations (WS)	Small – less than 0.1 acre	Over 100	Varies – greater than 1 acre	Weeds that have spread rapidly and are now beginning to increase in infestation size
Ubiquitous – Few to Many Large or Continuous Infestations (U)	Large – greater than 0.1 acre	Varies	Large – greater than 5 acres	Weeds that have already spread and grown considerably in infestation size

[1] An infestation is defined here as the patch of a particular weed species mapped during surveys. It is generally close to 100% cover by the invasive weed.

[2] Total infestation area is the total area of mapped infestations.

Source: EDAW 2004

Table 7-4 Distribution Profiles for Invasive Weeds in the Lower Putah Creek Riparian Corridor				
Weed	Avg. Infestation Size (acres)	Number of Infestations	Total Acres	Profile Type
Almond	0.01	26	0.3	I
Arundo	0.05	406	21	WS
Black locust	0.03	16	0.5	I
Catalpa	0.003	6	0.02	I
Edible fig	0.01	55	0.5	I
English ivy	0.004	1	0.004	I
Eucalyptus	0.1	302	24	U
Eurasian watermilfoil, parrot's feather	0.2	39	9	U
Fennel	0.01	9	0.09	I
Himalayan blackberry	0.1	241	22	U
Jubata grass; Pampas grass	0.04	1	0.04	I
Milk thistle	0.1	8	0.7	I
Pepper tree	0.01	10	0.1	I
Perennial pepperweed	0.1	143	18	U
Tamarisk	0.03	393	10	WS
Tree-of-heaven	0.04	123	5	WS
Tree tobacco	0.01	31	0.2	I
Vinca	0.004	1	0.004	I
Virginia creeper	0.02	4	0.06	I
Yellow starthistle	0.6	28	16	U
Total		1843	127.52	
Source: EDAW 2004				

weeds account for about 36 acres, or 28% of all invasive weed infestations in the riparian corridor. The five remaining mapped invasive weeds, including eucalyptus, Himalayan blackberry, Eurasian watermilfoil, perennial pepperweed, and yellow starthistle, are all considered ubiquitous with extensive infestations throughout much of the riparian corridor. These five weeds together account for 89 acres, or 70%, of all invasive weed infestations in the riparian corridor.

Almond

Almond is a weed characterized as an incipient population that has spread into the corridor from old orchards. Almond is growing mostly on the upper banks and top of bank terraces within the creek profile. It was mapped at 26 locations totaling 0.3 acre. It was found in

Reaches 4 and 5 adjacent to orchards or agricultural fields. While there were more patches mapped in Reach 5, Reach 4 had the largest patch totaling 0.11 acre. In Reach 5, the almond trees occur below Winters Road bridge and are scattered along the creek from the Yolo Housing Authority property to the I-505 crossing. In Reach 4, the trees are found in one main infestation across from an orchard.

Arundo

Arundo is a weed that is characterized as widespread, with numerous small infestations that have spread throughout the creek. Arundo was mapped at 406 locations throughout all seven reaches for a total of 21 acres. It grows mainly in the high-flow channel, on gravel bars, and along the lower bank of the creek. Most infestations are thick stands that preclude the growth of any other plants. The largest contiguous infestation mapped was approximately 0.8 acre. Reach 5 has the greatest amount of arundo, with 178 infestations mapped, totaling 10 acres. Large-sized (e.g., greater than 0.05 acre) infestations of arundo begin just downstream of the PDD and continue to the confluence of Putah Creek with Dry Creek. Reaches 4 and 7 also have major infestations. Reach 7 (Pleasants Creek) likely has more infestations than were mapped because large stretches of the creek were inaccessible. Pleasants Creek may be contributing to the large infestations found downstream in Reaches 4 and 5. Reaches 1, 2, 3, and 6 are less infested by arundo than the other reaches and Reach 3 has the fewest infestations, with only three small populations mapped.

Many infestations of arundo have been removed subsequently to the 2002 surveys. In 2002 and 2003, several acres of infestations immediately below the PDD and at the confluence of Putah Creek and Dry Creek were removed through a grant provided by the CALFED Bay-Delta Authority to Team Arundo del Norte and under contract with the LPCCC. The City of Davis and Los Rios Farms removed arundo on property near the Yolo Bypass in 2003. Additional infestations were removed prior to the surveys. Substantial infestations were removed along Pleasants Creek in 2001 by California Department of Forestry crews with funding by a USFWS Partners for Wildlife grant and private landowner funds. The work was conducted to stabilize creek banks that were eroding away quickly, aided by arundo that clogged the channels. Substantial infestations were removed by volunteers with the Putah Creek Committee at Winters Putah Creek Park in conjunction with habitat restoration in the late 1990s. Substantial infestations were also removed below Mace Boulevard in the late 1990s by volunteers with the Putah Creek Council and by the City of Davis.

Black Locust

Black locust is characterized as an incipient population. Black locust was documented in 16 locations totaling 0.5 acre. It grows from the high-flow channel all the way up to the top of bank terrace. Small infestations occur in Reaches 3, 4, 5, 6, and 7, but not in Reaches 1 and 2. It is evenly scattered across Reaches 3 through 6, while Reach 7 has small groupings of trees in one main area. The largest patch of black locust mapped is in Reach 3 and is a total of 0.15 acre.

Catalpa

Catalpa is characterized as an incipient population. Catalpa was mapped at six locations along the creek for a total of 0.02 acre. The trees typically are found growing on both the lower and upper banks of the creek. Most mapped infestations are individual trees, five of which are found in Reach 4. In Reach 4, the scattered individuals are concentrated in one area near the beginning of Reach 5. Only one tree was found in Reach 5. Catalpa trees are most likely escaped ornamentals from nearby landscaped areas or, in some cases, may have been planted.

Edible Fig

Edible fig is characterized as an incipient population in the lower Putah Creek riparian corridor. Edible fig was mapped at 55 locations and totals 0.5 acre. Fig trees are found growing mainly in the high-flow channel and along the lower banks, areas which satisfy its moisture requirements.

Most infestations mapped are individual trees. The reaches with the highest number of fig trees are Reaches 5 and 6, with decreasing amounts upstream and downstream. No individuals were found in Reach 1.

English Ivy

English ivy is an incipient population, with only one infestation of this weed found during the surveys. It is in Reach 5 and is approximately 0.004 acre. It is likely a garden escape.

Eucalyptus

Eucalyptus is characterized as a ubiquitous weed growing throughout most of the lower Putah Creek riparian corridor. The majority of eucalyptus trees are growing on the upper banks and top of bank terraces, but a large proportion is also growing on the lower banks. The majority of eucalyptus trees in the lower Putah Creek riparian corridor are red gum. They comprise a total of 302 locations and 24 acres of infestations. Reaches 3 and 4 are the most infested, although Reaches 2 and 5 also have extensive areas of eucalyptus stands. The largest stand mapped is in Reach 5, totaling 1.2 acres. Small, satellite infestations exist in Reaches 1, 6, and 7. In some cases, these smaller patches are intentional plantings in landscaped settings.

Eurasian Watermilfoil, Parrots Feather

The majority of infestations mapped along Putah Creek were Eurasian watermilfoil. It is considered ubiquitous and was found in nearly continuous infestations throughout major portions of the creek open-water channel. Eurasian watermilfoil typically grows in the low-flow channel, but one infestation was found growing on the lower bank along the creek. The population of this weed can vary considerably from year to year in response to changes in flows, temperature, and other conditions. Only one infestation was identified as parrot's feather. It was found in the Yolo Bypass near the Putah Creek sinks in Reach 1 (0.01 acre). The remaining 38 infestations were Eurasian watermilfoil, which totaled approximately 9 acres. The major infestations of Eurasian watermilfoil were located in Reaches 4 through 6, with smaller amounts in Reaches 1 and 2. Watermilfoil was not located in either Reach 3 or 7 during surveys. However, the plant could have been submerged and obscured by the turbid water in Reach 3 during surveys. Reach 7, Pleasants Creek, has only seasonal water and limited water was present at the time of the survey. The lack of perennial water likely prevents establishment of the weed there.

Fennel

Fennel is characterized as an incipient weed population currently restricted to nine mapped locations in Reach 6 totaling 0.09 acre and some unmapped terrace locations in Reach 1. It grows in the high-flow channel up to the top of bank terrace. Most infestations are small (0.01 acre) and scattered, but the largest infestation is approximately 0.04 acre.

Himalayan Blackberry

Himalayan blackberry is characterized as a ubiquitous weed growing throughout much of the riparian corridor. The species usually grows in the high-flow channel and along the lower banks of the creek, but at times is found up to the top of the bank terrace. It was mapped at 241 locations totaling 22 acres of infestations located in the entire lower Putah Creek watershed riparian corridor, with the exception of Pleasants Creek (Reach 7). Reach 5 has the largest infestation area, with 89 occurrences totaling nearly 10 acres. Reaches 1, 3, 4, and 6 have smaller amounts, although those reaches generally have large, scattered patches distributed throughout half or more of each reach. The largest infestation mapped was 0.8 acre found in Reach 1. Reach 2 appears to be the least infested area along lower Putah Creek, with only a few small patches that were mapped. However, it is likely that Himalayan blackberry is more extensive than what was mapped because it was often obscured by taller vegetation during surveys.

Jubata Grass/Pampas Grass

Jubatagrass or Pampas grass is an incipient population that was found at one location along the creek. It was approximately 0.04 acre in size and growing in the high-flow channel in Reach 6. The specimen could not be identified to species, however, because it was observed from a distance and not accessible to surveyors. It may have propagated from other plantings located at the mouth of Pleasants Creek.

Milk Thistle

Milk thistle is an incipient weed population found at eight locations and totaling 0.7 acre. It is an annual plant, so the population extent may vary considerably from year to year. Most of the infestations were located on the upper banks or top of bank terrace along the creek. It was found in six locations within Reach 4 interspersed within yellow starthistle. The remaining two small infestations were found in Reach 1. The largest infestation was in Reach 3 and totaled 0.28 acre.

Pepper Tree

Pepper tree is characterized as an incipient population in the riparian corridor. It is found growing on the upper bank and top of bank terraces within the creek profile. It is currently found at only 10 sites totaling 0.1 acre in Reaches 5 and 7. The largest number of occurrences (five), as well as the largest infestation (0.09 acre), are located in Reach 5. Most of the infestations are small, scattered patches around the Winters Road bridge. In Reach 7, two infestations were found close together.

Perennial Pepperweed

Perennial pepperweed is characterized as ubiquitous in lower Putah Creek, although it is largely restricted to Reach 1. Perennial pepperweed grows mainly on the upper banks and top of bank terrace in areas subject to flooding. It is also occasionally found on lower banks and in the high-flow channel. The population occurs in 143 locations totaling 18 acres. The largest infestations are found in Reach 1 in an area adjacent to agricultural fields in a levee bounded floodplain. The infestations mapped in Reaches 2, 3, and 4 were primarily small, scattered patches and perennial pepperweed were not found during surveys in Reaches 5 and 7. Only one patch was located in Reach 6. The largest infestation covers approximately 2.4 acres in Reach 2.

Tamarisk

Tamarisk is characterized as widespread in the riparian corridor, with numerous small infestations found in all but Reaches 6 and 7. Tamarisk typically grows in the high-flow channel and along the creek's lower banks. However, some infestations are located on the upper bank and top of bank terrace. There are 393 mapped infestations totaling 10 acres. The heaviest infestations are in Reaches 1 and 4, though it is also prevalent in Reaches 2 and 3. Only a small amount of tamarisk was found in Reach 5 near the Winters Road bridge. The most extensive patch was mapped in Reach 1 and covered 0.27 acre. Additional patches of tamarisk were removed along Putah Creek in the late 1990s prior to the survey. A few were removed by volunteers with the Putah Creek Council on or near the UC Davis Putah Creek Riparian Reserve, and some were removed just downstream of Mace Boulevard by the City of Davis.

Tree-of-Heaven

Tree-of-heaven is characterized as widespread with numerous small populations found throughout the riparian corridor. It was mapped in 123 locations totaling 5 acres of infestations. Tree-of-heaven grows mainly on the upper banks and terrace, but occasionally is found in the channel and on lower banks. Tree-of-heaven occurs in every reach. Reach 7 is the most infested reach and Reaches 1 and 2 are the least infested. The largest infestation is approximately 0.38 acre.

Tree Tobacco

Tree tobacco is considered an incipient population. It was mapped at 31 locations totaling 0.2 acre. Tree tobacco is found on the top of bank terrace, usually in open areas or along road cuts. Infestations are most extensive in Reach 6, with 21 small infestations that total 0.1 acre. Patches occurring in Reaches 2, 3, and 5 are currently few in number and small in size. No infestations were found in Reaches 1, 4, or 7.

Vinca

Vinca is an incipient weed that was found growing only as a single small patch that is 0.0004 acre or 174 square feet. It grows along the top of the bank terrace.

Virginia Creeper

Virginia creeper was mapped at four locations totaling 0.06 acre. This species appears to be colonizing small areas within Reaches 2 and 5. Three of the four infestations were found in Reach 5, but both reaches had very similar maximum acreage for an infestation; Reach 2 was 0.025 acre and Reach 5 was 0.032 acre. These infestations were found growing on trees on the top of bank terrace.

Water Hyacinth

Water hyacinth has previously been found in lower Putah Creek. However, no infestations were found during the 2002 surveys. It is likely that this weed will appear again because aquatic weed lifecycle patterns change from year to year in response to variations in flood-flow regimes, available propagules, and other factors.

Yellow Starthistle

Yellow starthistle is considered a ubiquitous weed in the watershed. It was mapped at 28 locations in all reaches except for Reach 5. Yellow starthistle occurs predominantly on the top of bank terrace, but occasionally is found along the banks of the creek. The total infested area mapped was 16 acres. The largest infestations occurred in Reach 7, where large fields used for grazing are found adjacent to the creek. Heavy infestations also were found in Reaches 2 and 6, with only a few infestations found in Reaches 1, 3, and 4. The largest infestation mapped occupied approximately 5.6 acres.

COMPARISON OF CURRENT DISTRIBUTION WITH USFWS INVASIVE SPECIES MAP

In 1993, the USFWS published its results on resource inventories conducted for the Report to Congress – Reconnaissance Planning Report – Fish and Wildlife Resource Management Options for Lower Putah Creek, California (USFWS 1993). The mapped inventory covered the mainstem Putah Creek riparian corridor between Monticello Dam and the Yolo Bypass. As part of the resource inventories, land use and habitat cover types within the planning area were assessed including invasive weeds mapping. The invasive weeds mapped during the

USFWS project included eucalyptus, tree-of-heaven, tamarisk, and arundo. The populations of those four species were mapped using aerial photographs, as well as field mapping during canoe, car, and foot surveys. The USFWS maps were compared to the maps created during the WMAP surveys to assess any major differences in the distribution of the four weeds that may be indicative of the rate and extent of their spreading to new areas of the riparian corridor. While it is likely that there are some information gaps in both the USFWS and current WMAP studies, the following comparison provides some insight into the changes that have occurred over the 10-year period between the studies.

Arundo

Arundo appears to have spread downstream substantially during the 10-year period between studies. Arundo first appears on the USFWS maps immediately downstream of the PDD, with no infestations recorded in the interdam reach. On the USFWS maps, a substantial number of stands were mapped in the vicinity of the PDD and downstream near the confluence of Putah Creek and Dry Creek. In contrast, in 2002, arundo was mapped at 19 locations in the interdam reach, with the majority of those infestations located around the confluence of Pleasants Creek and Putah Creek. It is possible that populations of arundo existed near the confluence with Pleasants Creek in 1991, but were not recorded during the surveys. Below the PDD, in Reach 5, arundo appears to have spread downstream, including new infestations on the south side of the creek, downstream of the Winters Road bridge, and near the Yolo Housing Authority property below the Winters Road bridge. New infestations are now present in Reach 2 approximately 1 mile south of I-80, and in Reach 1 near the Yolo Bypass.

Some infestations, which have since been removed, were present during or subsequent to the 1991 surveys. Infestations were removed during the mid to late 1990s in Winters Putah Creek Park and downstream of Mace Boulevard in the upper portion of Reach 1. Those populations were removed by volunteers with the Winters Putah Creek Committee, Putah Creek Council, and the City of Davis.

Eucalyptus

By the early 1990s, eucalyptus was already widespread throughout the riparian corridor below I-505. On the USFWS maps, it was first shown to occur just upstream of the I-505 bridge. Based on the 2002 survey, eucalyptus stands now occur farther upstream, just below the Winters Road bridge in Reach 5, possibly indicating a population expansion adjacent to residences. Eucalyptus infestations also appear to have spread and expanded in portions of Reach 5 and continuing into Reach 4, including upstream and downstream of Stevensons Bridge on the creek's northern bank, the northern bank adjacent to the UC Davis Aquaculture Facility, and within the UC Davis Riparian Reserve from I-80 to Old Davis Road. In Reach 2, infestations appear to be more extensive on the north bank between river mile 5 and 6.

Tamarisk

The distribution of tamarisk is similar between the USFWS maps and the 2002 maps. However, there are indications of population expansions. It appears that the quantity of infestations upstream of Stevenson's Road may be greater now than it was in 1991. There also appears to be a substantial number of new infestations on the south side of Putah Creek in Reach 2, approximately 2.5 miles south of Mace Boulevard.

Tree-of-Heaven

The USFWS map includes only a single stand of tree-of-heaven in between Monticello Dam and PDD in Reach 6, along State Route 128. During the 2002 surveys, 17 infestations were mapped in that reach. Many of the recently recorded infestations occur along Lake Solano and at the confluence with Pleasants Creek and Putah Creek Road, although there are additional patches scattered throughout Reach 6. There also appears to have been a substantial increase in the distribution and size of new infestations in Reach 5 upstream and downstream of Winters Road bridge, as well as scattered new infestations continuing downstream into Reach 4.

Tree-of heaven tends to grow in widely separated patches near the tops of the stream banks. It is not distinguishable in aerial photographs nor is it visible from canoes on the creek channel, the two primary methods used by USFWS to conduct the surveys. It is likely that the extent of tree-of-heaven was underestimated during prior surveys, and that the plant continues to grow and spread.

7.3.3 PRIORITIZATION OF WEED SPECIES FOR MANAGEMENT EFFORTS

Implementing any weed management program depends on landowner participation and funding availability (and often, volunteer labor). Nonetheless, within these constraints, weed control efforts will be most effective when guided by a comprehensive strategy for maximizing their benefits. Such strategies prioritize species and sites for removal efforts to maximize available resources.

Prioritization of species should consider their distribution (i.e., acreage infested and size of infestations), invasiveness, removal costs, and how they affect physical processes, biological communities, and human uses. These attributes indicate the effort required to control a species, the benefits of that control, and the impacts that will likely occur in the absence of any control effort.

Prioritization of individual sites (i.e., infestations) should consider the human uses, structures, and sensitive biological or other (e.g., cultural) resources affected by the infestation (or that could be affected by its removal), the potential for the infestation to expand or to serve as the source of propagules establishing additional infestations, and the effort required to eradicate the infestation. These attributes indicate where the greatest benefits can be attained and further invasion prevented.

As a step towards such a strategy, Table 7-5 provides a preliminary prioritization of the invasive weed species found along lower Putah Creek. Though all of these species are considered invasive species that are important to control in the lower Putah Creek riparian corridor, available resources are not sufficient to remove all of them simultaneously. Therefore, further prioritization is necessary.

Table 7-5
Attributes and Abatement Priority of Invasive Weeds in the Lower Putah Creek Riparian Corridor

Weed	Effects Physical-Biotic-Human[1]	Invasiveness[2]	Control Cost (per unit area)[3]	Total Acres	Profile Type
Level 1 Species[4]					
Arundo, giant reed *Arundo donax* (perennial grass)	H-H-H	M	H	21	WS
Tamarisk *Tamarix* spp. (evergreen shrub)	H-H-H	H	H	10	WS
Edible fig *Ficus carica* (deciduous tree)	L-H-L	H	L	0.5	I
English ivy *Hedera helix* (perennial vine)	M-H-L	H	L	< 0.1	I
Eucalyptus[5] *Eucalyptus* spp. (evergreen tree)	M-H-H	H	H	24	U
Fennel *Foeniculum vulgare* (perennial herb)	L-H-L	H	H	< 0.1	I
Himalayan blackberry[5] *Rubus discolor* (evergreen shrub)	M-H-M	H	H	22	U
Parrots feather *Myriophyllum aquaticum* (aquatic)	H-H-H	H	H	< 0.1	I
Pepper tree *Schinus molle* (deciduous tree)	M-H-L	M	H	0.1	I
Tree-of-heaven *Ailanthus altissima* (deciduous tree)	L-H-M	M	H	5	WS
Vinca, periwinkle *Vinca major* (perennial groundcover)	M-H-L	M	H	< 0.1	I
Level 2 Species[4]					
Eurasian watermilfoil *Myriophyllum* spp. (aquatic - submergent)	H-H-H	H	H	9	U

Table 7-5 Attributes and Abatement Priority of Invasive Weeds in the Lower Putah Creek Riparian Corridor					
Weed	Effects Physical-Biotic-Human[1]	Invasiveness[2]	Control Cost (per unit area)[3]	Total Acres	Profile Type
Jubata grass, Pampas grass *Cortaderia jubata. C. selloana* (perennial grass)	M-M-M	M	L	< 0.1	I
Perennial pepperweed *Lepidium latifolium*	H-H-L	H	H	18	U
Tree tobacco *Nicotiana glauca* (deciduous shrub)	L-M-L	M	L	0.2	I
Virginia creeper *Parthenocissus quinquefolia* (deciduous vine)	L-M-L	L	L	0.06	I
Yellow starthistle *Centaurea solstitialis* (annual herb)	H-H-L	M	L	16	U
Level 3 Species[4]					
Almond *Prunus dulcis (P. americana)* (deciduous tree)	L-M-L	L	L	0.3	I
Black locust *Robinia pseudoacacia* (deciduous tree)	L-L-L	M	H	0.5	I
Catalpa *Catalpa bignonioides* (deciduous tree)	L-L-L	M	L	< 0.1	I
Milk thistle *Silybum marinum* (annual/biennial herb)	L-L-L	L	L	0.7	I

Notes:

1 – Physical process effects are based on Criterion 1.1 and biotic effects are based on Criteria 1.2-1.4 of the California Invasive Plant Council (CalIPC) plant assessment form (PAF) (CalIPC 2003), and if available, on existing CalIPC ratings; human effects are detrimental effects on infrastructure, buildings, agriculture, recreation, or other human uses based on professional judgment of EDAW ecologists.

2 – Based on CalIPC criteria and scoring methodology for invasiveness (CalIPC 2003), and if available, existing CalIPC ratings.

3 – Ratings are based on costs per treatment and the likely number of treatments required for control; species with persistent soil seed banks or spreading via below-ground stems were rated "High," as were species requiring large amounts of biomass removal. Data sources included available literature (particularly the reviews in Bossard et al. 2000), data collected for the lower Putah Creek WMAP, and professional judgment of EDAW ecologists.

4 – Priority classification is: Level 1 species – I or WS species with either high invasiveness or a high rating for at least one effect type; Level 2 species – species not satisfying criteria for high priority but with at least moderate invasiveness and at least one effect type rated moderate; and Level 3 species – species with either all effects rated low or low invasiveness.

5 – Eucalyptus and Himalayan blackberry, though ubiquitous, were placed in the Level 1 category rather than in Level 2. Eucalyptus grows fast and high removal costs rise sharply as it grows, based on tree mass, elevating the importance of removing trees as soon as possible; Himalayan blackberry causes substantial adverse geomorphic effects (traps sediment, slows flows, and cuts off floodplain access); also, recent progress has been made on Putah Creek in developing cost-effective Himalayan blackberry abatement strategies, making it feasible to restore infested areas.

Source: EDAW 2004

The invasive weeds have been grouped into three priority levels based on the differences in their attributes. Those species placed in Level 1 have incipient or widespread distribution patterns and are either highly invasive in general or known to cause substantial impacts. Arundo, fennel, and vinca are examples of such species. In the absence of control measures, these are species whose effects are expected to increase the most in the near future. Species that are already ubiquitous, or that are less invasive and whose infestations cause lesser impacts, were placed in the moderate priority category (Level 2). Those species both with a relatively low level of invasiveness and causing relatively low levels of effects (in all effect categories) were placed in the lowest priority category (Level 3).

Because removal costs have not been well documented for many species, this attribute was not uniformly used to assign species to a priority category. However, as species removal costs become better known, species priority levels should be reassessed if their removal costs are substantially higher or lower than most other species. For instance, eucalyptus was raised to priority Level 1 due to its high cost of removal, which also increases rapidly as eucalyptus grows.