Setback Recommendations to Conserve Riparian Areas and Streams in Western Placer County

Prepared for:

Placer County Planning Department

Prepared by

Jones & Stokes in cooperation with **PRBO Conservation Science**

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Contents

Page

Tables

Page

Acronyms and Abbreviations

NCCP	Placer County Natural Communities Conservation Plan
HCP	Habitat Conservation Plan
RSPZs	Riparian and Stream Protection Zones
DFG	California Department of Fish and Game
USFWS	U.S. Fish and Wildlife Service
NOAA Fisheries	National Oceanic and Atmospheric Administration National Marine Fisheries Service
CEQA	California Environmental Quality Act
In	Inches
km	kilometers
Mi	mile
m	meters
Ft	Feet
PCWA	Placer County Water Authority
SOCs	synthetic organic compounds
DO	dissolved oxygen
CAFOs	concentrated animal feeding operations
N2	atmospheric nitrogen
NH4+	ammonia
NO2-	nitrite
NO3-	nitrate
O2	oxygen
SOCs	Synthetic organic compounds
PCBs	polychlorinated biphenyls

DDT	dichlorodiphenyltrichloroethane
Delta	San Joaquin Delta
C	Celsius
F	Farenheit
mg/l	milligrams per liter
M/sec	meter per second
Ft/sec	feet per second
SRA	Shaded riverine aquatic

Chapter 1
Introduction

Riparian areas provide important ecological functions (Table 1-1). They occupy the land between stream channel banks and adjacent uplands, and generally correspond to stream floodplains. These areas are transitional between terrestrial and aquatic ecosystems, and they contain gradients in hydrology, soils, ecological processes and biota (Brinson et al. 2002). Consequently, they perform ecological functions that are distinct from other components of the landscape. For example, riparian areas convey floodwaters and are important sites of denitrification, which returns nitrogen to the atmosphere. In western Placer County, they also provide essential habitat areas for a high diversity of aquatic and terrestrial wildlife species (Zeiner et al. 1988, 1990a,b; Moyle et al. 1996), including numerous threatened, endangered, and other special-status species that have been proposed for coverage under the Placer County Natural Community Conservation Plan (NCCP) and Habitat Conservation Plan (HCP) for the Phase I Planning Area (Jones & Stokes 2004a).

Because these areas provide such important ecological functions (including fish and wildlife habitat), a number of measures have been proposed to conserve riparian areas and aquatic ecosystems; these measures include establishing zones with land use restrictions (i.e., setbacks) around streams and riparian areas. Setbacks from streams and riparian areas have been widely recognized as necessary conservation measures. For example, the *Placer Legacy Open Space and Agricultural Conservation Program Implementation Report* (Placer County Planning Department 2000), which provided direction for development of a Placer County NCCP/HCP, identified Riparian and Stream Protection Zones (RSPZs) as an important component of the NCCP/HCP. Non-development setbacks encompassing and adjacent to riparian zones and streams are routinely recommended by local, state, and federal agencies including the Placer County Planning Department, the California Department of Fish and Game (DFG), the U.S. Fish and Wildlife Service (USFWS), and the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries). These agencies have identified a need in western Placer County (and elsewhere in the Sacramento Valley) to develop a strong scientific foundation for recommending stream and riparian setbacks that include buffers to reduce effects from adjacent land uses.

The current study was designed to support efforts by the Placer County Planning Department to develop this scientific foundation for the establishment of stream and riparian setbacks. Its purpose was to review existing literature and make specific recommendations for riparian setbacks—particularly the width of such setbacks—that can be used in the California Environmental Quality Act (CEQA) or NCCP/HCP processes.

This report summarizes the results of the review. Each chapter addresses a set of related ecological functions performed by riparian areas and streams, as listed below.

- Hydrologic and geomorphic functions (e.g., groundwater recharge, sediment transport).
- Biogeochemical functions (e.g., nutrient cycling, degradation of contaminants).
- Provision of salmonid habitat.
- Provision of riparian plant habitat.
- Provision of wildlife habitat.

Each chapter describes the pertinent functions mechanistically, reviews the effects of human alterations on the functions, assesses the relationships between setback width and human activities, and concludes with recommendations for setback widths. The recommendations are intended to provide for long-term conservation of the relevant function by protecting the riparian area as well as a defined buffer that will reduce the effects of adjacent land uses on riparian and aquatic systems. In these recommendations, and throughout the report, all distances refer to only one side of streams.

The report concludes with an overall setback recommendation that includes setback widths and guidance regarding uses of setback land that may be compatible with resource conservation.

Table 1-1. Ecological Functions of Riparian Ecosystems[a]

Hydrologic and Geomorphic Functions
Recharge of groundwater
Storage of surface water
Conveyance of floodwaters and other overland flows
Transport of sediment
Storage of sediment
Biogeochemical Functions
Production of biomass (i.e., primary production)
Storage of carbon in vegetation and soil
Cycling of phosphorus
Cycling of nitrogen
Cycling of micronutrients
Adsorbtion, storage, and transformation of non-nutrient metals (e.g., mercury)
Adsorbtion, storage, and degradation of pesticides and hydrocarbons
Habitat Functions
Sustenance of characteristic plant associations
Sustenance of aquatic animal habitats
Sustenance of terrestrial animal habitats

[a] Based on lists of functions in Keddy 2000 and Brinson et al. 2002.

Chapter 2
Hydrologic and Geomorphic Functions

Overview

Hydrologic and geomorphic functions involve the transport and storage of water and sediment. Streams—comprising stream channels and floodplains—are integral to the provision of those functions. Riparian vegetation occupies floodplains; for the purposes of this report, riparian areas may be considered synonymous with floodplains. Sediment and water are transported to streams from throughout the watershed; upon reaching the stream, sediment and water move down the stream and occasionally outwards onto the floodplain. In response to these inputs of water and sediment, the form of stream channels and floodplains changes. These dynamic changes can in turn affect most ecological functions provided by riparian areas and aquatic ecosystems. This chapter describes these processes and the effects on them caused by human activities. The chapter concludes with an assessment of the relationship of setback width and human effects, and offers the project team's recommendation for setback widths to conserve hydrologic and geomorphic functions.

Effects of Human Alterations on Movement of Water and Sediment to Riparian Areas and Streams

Watershed Hydrology

In the absence of human alterations (e.g., interbasin water transfers), streamflows originate from the precipitation falling throughout a stream's watershed. Rainfall is the predominant form of precipitation in most of western Placer County. Before reaching a stream, precipitation may infiltrate to become groundwater or return to the atmosphere through evapotranspiration. Human alterations affect the proportion of precipitation following each of these pathways, and thus the quantity and timing of streamflows, which in turn influences geomorphic functions in the stream corridor.

Evapotranspiration

Evapotranspiration is the loss of water to the atmosphere due to the diffusion of water vapor from the interior of plant leaves (transpiration) and from soil and other surfaces (evaporation). It can dominate a watershed's water balance and can influence soil moisture content, groundwater recharge, and streamflow.

Air temperature and humidity determine the potential rate of evapotranspiration, whereas water availability determines its actual rate. Under cool or moist conditions, water availability does not limit evapotranspiration; actual and potential evapotranspiration are equal. Under drier and warmer conditions, as surfaces and soils dry, plants reduce their use of water by a combination of closing their leaf pores (i.e., stomata), changing leaf angles, losing leaves, becoming dormant, or dying (Barbour et al. 1998). Thus, under dry and warm conditions, actual evapotranspiration is limited by water availability.

Not all water is available for evapotranspiration. Only water stored at the earth's surface (i.e., surface water and water intercepted by surfaces) or in soils is available for evapotranspiration. Therefore, the timing of precipitation and the time water resides in a watershed strongly influence actual evapotranspiration.

Western Placer County has a Mediterranean-type climate, characterized by concentration of rainfall during the coldest months of the year. Consequently, only water stored in soils, streams, and other water bodies is available for evapotranspiration during summer months when the potential evapotranspiration is greatest. During these months, vegetation can remove a substantial fraction of the water within riparian areas and streams. For example, in July in the Sacramento Valley, potential evapotranspiration is about 0.8 centimeters (cm) (0.3 inches [in]) per unit area each day (California Department of Water Resources 2004). This corresponds to about 18 acre-feet of water being transpired by 1.6 kilometers (km) (1 mile [mi]) of a riparian corridor 30 meters (m) (98 feet [ft]) wide on each side of a stream.

Human alterations can increase or reduce evapotranspiration. Importing water from other watersheds or withdrawing groundwater from below the rooting zone to irrigate agricultural lands and landscaping can increase evapotranspiration by increasing the availability of water. Removing vegetation or increasing runoff can reduce evapotranspiration. Alterations that remove vegetation include both the temporary removal of biomass (e.g., timber harvesting, woodcutting) and the permanent conversion of natural vegetation to developed land uses with impervious surfaces (e.g., roofs, paved roads). Alterations affecting runoff are described in the next section.

Runoff

There are three basic types of runoff.

- Overland flow.
- Subsurface flow.
- Saturated overland flow.

Each of these runoff types can occur individually or in some combination in the same locale. Despite involving belowground flow, subsurface and saturated overland flow are considered components of runoff because they are closely linked to overland flow.

Overland flow occurs when the rate of rainfall or snowmelt exceeds the rate of water movement into the soil (i.e., infiltration rate). The infiltration rate is affected by soil structure and moisture content (infiltration diminishes as water saturates a soil). Areas with natural vegetative cover and leaf litter usually have high infiltration rates. These features protect the surface soil pore spaces from being plugged by fine soil particles as a consequence of raindrop splash.

Overland flows may subsequently enter the soil as rainfall diminishes in intensity or ceases, or they may reach a stream channel before entering the soil. Slope and vegetation affect the speed of overland flow, and thus the portion that discharges directly into stream channels.

Subsurface flow is a storm-generated pulse of groundwater. Once in the soil, water moves in response to differences in hydraulic head (i.e., the potential for flow resulting from a difference in hydrostatic pressure at different elevations). Before a storm, where the water table slopes toward a stream, water moves down and into the stream channel as baseflow. During a storm, as rainwater infiltrates the soil, the water table can rise more rapidly near the stream than it does further upslope. This can happen when the soil near the stream has greater moisture content and a shorter distance to the water table than does soil upslope. As the water table becomes locally steeper, this newly arrived groundwater moves relatively rapidly towards the stream channel, mixes with baseflow, and increases groundwater discharge to the channel.

Saturated overland flow is a combination of direct precipitation and subsurface flows. Where the water table reaches or emerges from the surface, soils are saturated. Consequently, all rain falling on these soils, as well as emerging groundwater, flows downslope as overland runoff.

Human alterations increase runoff by reducing the soil's infiltration capacity (i.e., maximum rate of infiltration). Conversion of natural vegetation to developed land cover causes the greatest reduction in infiltration. However, agricultural lands also exhibit reduced infiltration capacity compared to natural vegetation. Heavy machinery, livestock, and even humans can compact soils, reducing infiltration. Moreover, removal of vegetation can expose the soil surface to the impacts of raindrops, reducing soil pore spaces and infiltration. In western Placer County, these alterations have affected extensive portions of the landscape. For example, along the major streams of western Placer County, approximately a quarter of the land < 20 m (66 ft) from the centerline of a stream, is in developed or agricultural land-cover (Jones & Stokes 2004a, 2004b).

Groundwater

Gravity causes water to move downward through soil until it reaches an area already saturated with water. The top of this saturated zone defines the groundwater table. However, the movement of groundwater may be quite complex. The permeability of sediments and rock strongly influences the rate of groundwater movement. Water moves easily through larger pores and more slowly through smaller pores. In addition, layers of sediment or rock with low permeability (i.e., confining beds) may severely restrict groundwater movement. Thus, where the permeability of sediments and rock varies considerably, complex patterns of groundwater movement may occur. Riparian areas typically have considerable variability in the permeability of their sediments.

Human alterations can affect groundwater through several different mechanisms. First, activities that affect runoff or evapotranspiration affect the proportion of precipitation that becomes groundwater. Second, because streamflows can be an important source of groundwater, alterations that reduce streamflows can also reduce inputs to groundwater. Third, alterations that affect the quantity of groundwater (i.e., groundwater withdrawals) can change the elevation of the groundwater table. Drainage ditches and tiles also lower the water table's elevation.

Erosion

Gravity, wind, and water transport soil to riparian areas and streams. Soil is dislodged when the force of wind, water, or gravity exceeds the forces holding soil in place. Several factors affect the balance of these forces: the soil's physical properties; vegetation structure; topography; and the quantity, concentration, and speed of runoff. Soil characteristics, such as lithology (i.e., rock or mineral content), cohesion, and granulometry (i.e., grain size association), influence the erodibility of soils. Vegetation reduces erosion by binding soil particles and by slowing wind and water (Brinson et al. 2002); accordingly, greater cover of vegetation reduces the potential for erosion. Because both velocity and shear stress increase with slope, the potential for erosion increases with the angle and length of upland slopes. Also, as more runoff is generated and concentrated (i.e., greater runoff depth), the force exerted by flowing water on the soil surface—and hence erosion— increases.

Gravity can also induce the slow downhill movement of soil and rock (i.e., soil creep) and mass failures such as debris flows. In steep terrain, mass failures can transport enormous quantities of sediment into riparian areas and stream channels. Mass failures are often triggered by intense rainstorms falling on saturated soils (Swanston 1991). Under such conditions, soil is particularly heavy due to the added water, and subsurface flows can reduce the forces that offset gravity. Although western Placer County generally has gently sloping topography, that is not conducive to mass failures, slopes can be steep along stream channels, particularly near the area's eastern boundary in the Sierran foothills.

The magnitude and distribution of erosion in watersheds affect the yield of sediment to the stream corridor. Soil erosion can occur gradually over a long period or it can be cyclic or episodic, accelerating during certain seasons or during certain rainstorm events (Grove and Rackham 2001). Erosion does not proceed at a uniform rate, because rainstorms are episodic events of varied intensity and because the forces binding soils continually change with temperature, moisture content, and vegetation structure.

Human activities strongly alter patterns of erosion and thus the quantity of sediment entering riparian areas and streams. In the Sacramento Valley and adjacent foothills, human-induced fine sediment loading is primarily due to changes in land use that both alter the vegetative cover and increase runoff. The three main land uses generating sediment in the region are agriculture, in-channel mining, and construction activities. The effects of silvicultural activities, though discussed in this section, are concentrated at higher elevations in the central and eastern portions of the county.

Agriculture generally exposes friable topsoils to raindrop erosion, which has the potential to generate large amounts of sediment (Waters 1995). In the Sacramento Valley and adjacent foothills, additional land is still being converted from natural vegetation to agriculture. Much of this new agricultural land is of marginal quality and on relatively steep slopes, and is consequently likely to generate more sediment than agricultural land with gentler slopes (Charbonneau and Kondolf 1993).

Gravel mining can increase fine sediments in streams and streambeds. Gravel mines are often in the active floodplain or even the stream channel itself, and because processing of aggregate occurs on site, this activity can add fine sediment directly to the stream and streambed. Gravel mining is on-going in the historic floodplains of at least two streams in western Placer County (EDAW 2004; Jones & Stokes 1999).

Forestry practices, including clear-cutting, skidding, yarding, site preparation, and road construction and maintenance, can substantially increase sediment input to streams. Poorly designed logging roads and skid trails are persistent sources of sediment. Open slopes with soils exposed by yarding activities, scarification, or by associated mass failures or fires erode easily (Chamberlain et al. 1991).

Residential development, industrial construction, streets and utilities, and other urban infrastructure elements can increase sediment movement to streams

(Waters 1995). Excavation for infrastructure construction and maintenance is a primary source of sediment transported to streams. Development on steep hillsides further increases erosion and transport of sediment (Renard et al. 1997).

In addition to these effects of general types of land use activities, roads, graded and recontoured land, and the routing of stormwater drainage can all spatially concentrate runoff, and hence increase both surficial erosion and the likelihood of mass failures.

Effects of Human Alterations on Water and Sediment Movement along Streams

Flow Regime

Streamflows originate in runoff and groundwater entering the stream channel. As this water moves along the stream it may follow several different pathways. Some water will evaporate from the surface of the flow. Some will enter the sediments underlying the channel and floodplain, where it will intermix with groundwater in a zone (i.e., the hyporheic zone) that can extend from several to more than a hundred meters from the channel (Brunke and Gonser 1997). (This hyporheic zone is habitat for invertebrates and microbes that have important roles in nutrient cycling and the degradation of pollutants.) Stream water entering the hyporheic zone may reenter the channel downstream; alternatively, in reaches where the water table is lower than the stream channel, the water entering the hyporheic zone may continue to flow away from the stream toward the water table. During high streamflows, the channel may not be able to convey the entire flow, and streamflows spill over the channel banks onto the floodplain, and may or may not reenter the channel downstream.

Streamflows are typically highly variable across days, seasons, and years. Most aspects of a stream's flow regime (i.e., the pattern of streamflow), including magnitude, frequency, timing, and duration, have consequences for sediment transport and channel form, and indirectly or directly affect organisms. For example, low flows can reduce the area of aquatic habitats. High flows can wash away eggs or, through sediment movement, can sustain or degrade habitats. Rapid declines in flow can strand fish.

Together with the pattern of water inputs from the watershed, channel form and vegetative structure determine a stream's flow regime. The slope, area, form, and roughness (i.e., irregularity of the surface) of the channel and floodplain surface determine the depth and velocity of streamflows, as well as their magnitude and duration.

As a stream's discharge (i.e., the volume of water discharged per unit time) increases, either flow velocity, flow area, or both must increase. Similarly, as water flows along a stream, the depth, velocity, and cross-sectional area of the flow change to maintain a constant discharge. This occurs because as more water enters than exits a section of channel, the volume of water in that section increases, changing the width and depth of the flowing water until the discharge entering the segment equals the exiting discharge. As width and depth change flow velocity changes.

Flow velocity is a product of slope (which causes water to accelerate as it moves downhill) and the surface over which the water flows (the character of which can impede or facilitate the water's passage through friction or the lack of it). At a given slope, water velocity decreases as the roughness of the inundated surface increases. Vegetation, coarse sediment, and larger obstacles all increase roughness. For example, the encroachment of woody plants into a stream channel reduces the velocity of water, and consequently the channel's capacity to convey floodwaters before inundating the floodplain; for this reason, woody plants are removed from many stream banks to maintain floodwater conveyance.

Flow regime is changed to some degree by all human activities that alter the quantity or timing of water inputs to streams or the movement of flows along streams. Surface water diversions, groundwater withdrawals, and inter-basin water transfers change the quantity of water entering streams. When these waters are used for irrigation during California's summer dry season (and subsequently drain back to streams), they change the seasonality as well as the levels of flows. Conversions of land cover throughout the watershed affect the rate at which water enters streams. As described in *Watershed Hydrology* above, replacement of natural vegetation with agricultural or developed lands increases runoff. This increased runoff results in higher peak streamflows because, after rainstorms, runoff enters streams much more rapidly than does groundwater. Decreased infiltration is also associated with increased runoff; such decreased inputs to groundwater can reduce low flows, and can even convert a perennial flow regime to a seasonal or intermittent one. These changes are most dramatic along urban streams where much of the watershed consists of developed lands with a high proportion of impervious surfaces (Hollis 1975; Macrae 1996; Booth and Jackson 1997; Paul and Meyer 2001).

Interbasin water transfers are a particularly significant human alteration of flow regimes in western Placer County (Jones & Stokes 2004b). Water is diverted from the Bear River's watershed into Coon Creek, Doty Ravine and Auburn Ravine. Water is also diverted from the American River's watershed into Auburn Ravine. Because large quantities of water (about 20,000 acre-feet) are transferred by the Placer County Water Authority (PCWA) from the American River watershed to the City of Roseville, it is likely that interbasin transfers augment flows in the Dry Creek watershed as well (ECORP 2003).

Modifications of channels and floodplains also alter flow regime. Vegetation removal that is conducted to clear channels or that results from grazing, logging, or conversion to agricultural and developed lands can reduce roughness, thereby increasing flow velocities. Physical alterations to the channel and floodplain (e.g., channelization, levees, berms) also changes flow regimes. For example, the straightening and deepening of the channel to improve conveyance (channelization) speeds velocities and increases peak flows downstream. Dams and reservoirs can affect all aspects of flow regimes, and in some instances replace the previous flow regime with a new regime determined by the schedule of releases from a reservoir. Common downstream effects of reservoirs include a reduction in overall flows, reduced peak flows, and rapid changes in discharge (Stanford et al. 1996; Brinson et al. 2002). Along some Sacramento Valley streams, reservoir releases in conjunction with drainage from irrigated lands have increased summer flows, converting seasonal flow regimes to perennial ones.

Sediment Transport

Sediment transport is directly related to stream power. A stream's power is a product of its discharge, the specific weight of water (which is essentially a constant), and slope. Stream power represents the quantity of work that a streamflow can perform (i.e., the rate of potential energy expenditure per unit length). Most of this energy is dissipated overcoming friction at the channel and floodplain surface, but a small portion moves sediment.

The portion of stream power that moves sediment depends on several stream attributes. The movement of sediment downstream only occurs when the force exerted by water along the surface of the channel (shear stress) exceeds the forces holding sediment in place. The magnitude of shear stress and the forces that offset it are affected by the following factors.

- Flow depth and velocity.
- Channel morphology.
- Sediment size.
- Adhesion of particles.
- Binding of particles by roots.

Sediment transport is increased by conditions that concentrate the force of flowing water (e.g., confining flow to a narrower channel) or reduce the resistance of particles to their displacement (e.g., loss of vegetation and hence of roots).

Sediment transport in any given stream is greatest during peak flows. Not only does shear stress increase with flow depth and velocity, but the relationship between shear stress and sediment transport is non-linear (Gordon et al. 1992). In other words, the increased force exerted by peak flows results in a disproportionate increase in the capacity to transport sediment.

Human alterations affect sediment transport by changing flow regime or sediment inputs to streams, and by blocking the continuity of sediment delivery along a stream. Human effects on flow regime and sediment inputs have already been described in the flow regime and erosion sections of this chapter. The movement of sediment along a stream may be blocked by dams or reduced by pits from gravel mining. Dams block the downstream movement of coarser sediment from the upper portions of watersheds of most rivers and streams in the Sacramento Valley. In-stream gravel mining produces pits that trap incoming sediment (Mount 1995).

Effects of Human Alterations on Channel and Floodplain Form

The form of stream channels and their floodplains affects the important stream and riparian functions listed below.

- Transport and storage of sediment.
- Conveyance of floodwaters.
- Provision of floodplain habitats.
- Provision of aquatic habitats.

For example, the shape and gradient of channels affects the location of areas of sediment deposition and removal. Similarly, fish spawning and rearing habitats are affected by the interplay of channel geometry with flow depth, velocity, and the scour and deposition of sediments.

The form of a stream's channel and floodplain is a product of water and sediment inputs from the watershed, geologic constraints, channel or floodplain vegetation, and historic events. Consequently, changes in sediment inputs, flow regime, or vegetation cause changes in channel and floodplain form. These geomorphic responses can be complex because of interactions among these important factors. Flow regime, sediment transport, and vegetation influence each other; changes in channel and floodplain form likewise affect the growth of plants and the movement of water and sediment. Consequently, changes in a watershed may cause channels and floodplains to undergo complex patterns of change across decades.

Channel Morphology

In the absence of human alterations, the form of stream channels is not static, unless constrained by geology. Channel and floodplain morphology changes slowly in response to long-term changes in climate; it can also change rapidly in response to periodic intense storms or to massive inputs of sediments from slope failures.

Human alterations often cause changes in flow regime and sediment input that lead to unstable channels with rapidly changing forms. Unstable channels result from rates of erosion and sedimentation that are much more rapid than in comparable, but relatively unaltered, streams (Doyle et al. 2000). This instability can affect riparian and stream biogeochemical and habitat functions (Paul and Meyer 2001; Brinson et al. 2002).

Channel instability has both horizontal (channel bed) and vertical (channel banks) components. A longitudinal section of streambed is stable when the size and quantity of sediment entering the section equals the size and quantity of sediment carried downstream. If the capacity of flows to transport sediment changes (e.g., change in peak flows) without a corresponding change in sediment inputs, or vice versa, then net erosion or deposition will occur and the channel may become unstable. The rising (i.e., aggradation) or lowering (i.e., incision or degradation) of channel beds generally alters flows of groundwater and surface water through riparian areas by changing the elevation or slope of the water table, and by changing the discharge necessary for overbank flows.

The stability of channel banks is affected not only by the shear stress of flowing water, but also by the force of gravity pulling bank sediments downward, which can lead to mass failure of sections of bank (i.e., bank failure). The binding of sediment particles by plant roots can substantially reduce bank erosion. A tree's roots typically extend up to twice the radial distance of the tree's crown; thus, in western Placer County, trees up to 20 m [66 ft] from the channel may contribute to bank stability. Therefore, bank retreat (i.e., net linear recession of the bank) is increased not only by changes in flow regime that increase shear stresses, but also by removal of vegetation along the banks (Lawler et al. 1997).

Human alterations affect channel stability through changes of flow regime, sediment transport, or channel vegetation, or by placing structures along or in the channel. Human activities altering flow regime, erosion, and sediment transport are described in the respective sections of this chapter. Their net affect on channel form is to alter the balance between erosion and deposition along the stream channel, causing a corresponding change in channel form.

Channel bank vegetation is directly altered by grazing, channel maintenance, wood cutting and timber harvesting, land-cover conversion, and even by the trampling associated with intensive recreational use. All these activities may lead to bank retreat. With the exception of timber harvesting, these activities occur locally along western Placer County's streams (Placer County 2002; Appendix A)

Channel vegetation is also altered by activities that change flow regime, water table elevation, or channel stability. If changes to flow regime or water table elevation reduce water availability during the growing season, vegetation will be altered and will probably exhibit reduced roughness or a lower density of roots to bind bank sediments. Conversely, reduced flows may allow riparian vegetation to establish on lower-elevation surfaces within the channel, where establishment and survival were previously not possible because of scouring or prolonged submergence (Pelzman 1973). The latter scenario has occurred along a number of Sacramento Valley streams below dams (Pelzman 1973; CALFED 2000b). This encroachment of vegetation on the channel stabilizes channel sediments.

The changes in erosion, runoff, and peak flows associated with conversion of natural vegetation to developed land cover generally cause channel instability (Paul and Meyer 2001). Though channels may transiently aggrade with sediment eroded from construction sites, the higher flow peak flows associated with runoff from developed lands are capable of eroding and transporting more sediment (Wolman 1964). This tends to cause channel incision, bank retreat, or both, and a resulting increase in the channel's cross-sectional area. The slope and meanders of stream channels also may change (Riley 1998). Other changes in vegetation or land cover may cause effects comparable to those from conversion to developed lands. Incision is widespread along western Placer County's streams, and has reduced the area of floodplain inundated by floodflows, and thus detrimentally affected most riparian functions (Placer County 2002; EDAW 2004; Jones & Stokes 2004c).

All structures constructed in the channel or active floodplain to some degree alter flows and sediment erosion and deposition, and thus have consequences for channel form. The most substantial effects result from bank protection, berms and levees, and dams. Bank protection (e.g., stone revetment, riprap) is installed for the purpose of reducing lateral movement of the channel. Berms and levees restrict floodwaters to a small portion of the floodplain, and thus may create deeper and faster peak flows capable of eroding and transporting more sediment, which in turn may expand channel cross-sectional area. Berms and bank protection exist occur along western Placer County's streams, particularly at lower elevations. Other structures include numerous road crossings and about thirty dams (County of Placer 2002; DWR 2002; Bailey Environmental 2003; Foothill Associates 2004; Jones & Stokes 2004b)

The construction of dams to form reservoirs contributes to accelerated channel erosion below the dams and to changes in the particle size on the riverbed (Kondolf 1997). Water released from dams is relatively free of sediment, particularly coarse sediment (i.e., larger than 2 mm in diameter). The relatively sediment-free flow results in net erosion of channel bed and banks, often leading to channel incision. Without the input of coarse sediment from upstream, the area of gravel beds in the channel is reduced, and the remaining gravel is often of larger sizes that are not mobilized by flows released from the dam (i.e., armoring of the channel). Dams also reduce peak flows, resulting in a reduction of channel size and accumulation of finer sediment along and within the river channel (Kondolf 1997). Flashboard dams, however, may have lesser effects if removed during peak flows. Most dams in western Placer County are flashboards dams, and many are removed during peak flows (DWR 2002; Placer County 2002; Bailey Environmental 2003)

Stream channel shape is directly altered by channelization and in-channel gravel mining. As mentioned earlier in this chapter, channelization converts streams into deeper, straighter, and often wider shapes to improve conveyance of floodwaters. It increases peak flows and can promote channel instability, which may lead to lowering of the water table (Gordon et al. 1992). In-channel gravel mining removes material from the channel bed and thus lowers its elevation (Bravard et al. 1997).

Floodplain Morphology

The active floodplain is the geomorphic surface adjacent to the stream channel that is typically inundated on a regular basis (i.e., a recurrence interval of about 2–10 years or less). It is the most extensive low depositional surface, typically covered with fine overbank deposits, although gravel bar deposits may occur along some streams. The floodplain surface often contains abandoned channels or secondary channels (i.e., chutes).

The stream migrates laterally across the floodplain as the outside of the meander bend erodes and the point bar builds with coarse-textured sediment. This naturally occurring process maintains the cross section needed to convey water and sediment from the watershed.

Floodplains are built by two stream processes: lateral and vertical accretion. Lateral accretion results from differential erosion and deposition along the channel. In unconstrained rivers, bank retreat is concentrated on the outside (concave side) of bends in the channel (i.e., meanders), forming cut banks; deposition occurs on the inside (convex side) of bends, forming point bars. This difference in erosion and deposition along channel bends causes channels to migrate across the floodplain. Other floodplain features also arise through channel migration. Where bends become cut off at their base (because erosion joins their upstream and downstream ends), oxbow lakes are formed. Where higher flows cross over point bars, chutes may form. Channel shifts to old or new courses (i.e., channel avulsion) can occur during floodflows, and may cut off meander bends and change the channel's form.

Vertical accretion is the deposition of sediment on flooded surfaces. It occurs when flows exceed the channel's conveyance capacity, inundate the floodplain, and deposit sediment. Though most floodplain sediment is deposited through lateral accretion (Leopold et al. 1964), overbank flows and the associated vertical accretion have a significant effect on aquatic and floodplain habitats that are described in subsequent chapters of this report.

Lateral and vertical accretion are affected by human alterations that modify flow regime, sediment supply, and channel stability or that construct structures within the floodplain. Human alterations affecting flow regime, sediment transport, and channel form alter the rate of channel movement and the frequency of overbank flows. These alterations, including the effects of dams, have been described in the preceding sections of this chapter. All structures within the channel or floodplain alter flows and accretion to some degree. However, the most substantial alterations are bank protection, which is installed specifically to reduce lateral channel migration, and berms and levees, which restrict floodwaters, and thus vertical accretion, to a small portion of the floodplain.

Relationships Between Human Effects and Riparian Setback Width

Riparian setbacks can reduce the effects of human alterations on water and sediment inputs to streams; if they extend beyond the active floodplain, setbacks can also reduce direct effects on flow regime, sediment transport, and channel and floodplain morphology. However, many effects of human alterations on hydrologic and geomorphic functions would be relatively unaltered by setbacks.

There has been considerable research on the effects of natural riparian vegetation or managed buffers on the movement of runoff and suspended sediment. (This literature has been reviewed by Castelle et al. 1992; Wenger 1999; Brinson et al. 2002; Lowrance et al. 2002; Correll 2003). This research indicates that setbacks have three beneficial effects: slightly reducing the area of sediment sources in a watershed, increasing the distance of runoff and erosion sources from streams, and interposing a zone of vegetation with high roughness and high infiltration capacity between streams and sources of runoff and erosion. The roughness of both natural and managed vegetation can slow runoff and cause the deposition of sediment before it reaches the stream. This deposition of sediment increases with vegetation width; at any given width, deposition is greatest when flows are evenly distributed (not locally concentrated) and when vegetation and topography are uniform (Herrone and Hairsine 1998; Wenger 1999; Brinson et al. 2002).

Numerous studies document the effectiveness of managed or natural vegetation in removing suspended sediment, particularly sands and silts, from runoff before it reaches stream channels (Castelle et al. 1992; Wenger 1999; Brinson et al. 2002; Lowrance et al. 2002). (Because clay particles are very small [less than 2 μm], they remain suspended even in still water for hours, and thus are much more likely to remain in runoff.) If this sediment is deposited on the active floodplain, it may be only temporarily stored there before entering the stream channel. However, if sediment is removed from runoff before it reaches the floodplain, it is much less likely to be remobilized into the stream channel. Setbacks may also reduce the likelihood of mass failures on adjacent slopes by including susceptible terrain inside the buffer, where human alterations are less likely to cause mass failures (Rhodes 1994; Tang and Montgomery 2004).

There is considerable variation among the results of studies assessing the relationship between the width of buffers and sediment removal from runoff. A number of studies document narrow buffers (less than 10 m [33 ft]) removing substantial amounts of sediment from runoff (Castelle et al. 1992; Wenger 1999; Lee et al. 2000; Hook 2003). However, many of these have been short-term studies or studies of managed buffers that were conducted under a narrow range of conditions. Short-term studies probably underestimate the distance sediment is able to be moved across buffers because erosion is a highly variable process, largely associated with intense storms and other unusual events (Grove and Rackham 2001). Similarly, small-scale studies of managed buffers probably underestimate the quantity of sediment that is able to cross unmanaged buffers because natural topography and vegetation are quite varied, and can concentrate flow, have less roughness than managed vegetation, or provide additional sources of runoff or sediment at some locations. These findings are supported by other studies that have indicated wider buffers (20–60 m [66–197 ft]) are necessary to remove most sediments (Cooper and Gilliam 1987; Castelle et al. 1992; Davies and Nelson 1994; Wenger 1999). These include longer-term studies that have shown most sediment moving considerable distances into riparian areas (Cooper et al. 1987), and studies that document effects of excessive sedimentation on aquatic organisms in streams bordered by wide buffers (Megahan 1987 *in* Rhodes 1994).

Setbacks of sufficient width to include the entire active floodplain prevent structures and developed land uses from impeding overbank flooding and channel migration. Setbacks including the entire active floodplain also reduce direct effects of human activities on bank stability.

Recommended Setback Width to Conserve Hydrologic and Geomorphic Functions

For the purpose of long-term conservation of hydrologic and geomorphic functions, the project team recommends that riparian setbacks include the entire active floodplain, regardless of the current extent of riparian vegetation on that surface, and that an additional 30 m (98 ft) buffer be included within the setback. This width should be sufficient to substantially slow or infiltrate much of the runoff from adjacent uplands, and to remove excessive sediment from that runoff prior to its entering the active floodplain.

It is important to note that setbacks do not ameliorate many effects of human alterations on hydrologic and geomorphic functions. Some effects are offset only if the activities causing them are excluded from the setback. Examples of these activities include riparian vegetation removal, grazing, and channel modifications. Other alterations are only partially offset, such as the effects of developed or agricultural land cover on runoff and groundwater. Finally, other effects are not addressed by riparian setbacks. These include the effects of surface water diversions, groundwater withdrawals, and dams. Therefore, to conserve hydrologic and geomorphic functions, other measures are necessary in addition to setbacks.

Chapter 3
Biogeochemical Functions

Introduction

Biogeochemical functions cycle elements among compounds and locations by biological and geological mechanisms. For example, in the carbon cycle, photosynthesizing plants remove carbon from the atmosphere; through respiration, plants, animals, and microbes return carbon to the atmosphere. A substantial quantity of carbon is stored in these organisms and in the organic matter derived from them. Nutrient cycles are essential to ecosystem functions; moreover, such cycles facilitate the transformation and degradation of contaminants entering these ecosystems.

All terrestrial habitats provide some biogeochemical functions. However, riparian areas are particularly important for nutrient and other element cycles because they are ecotones (transitional zones) between terrestrial, fluvial, and groundwater systems. Consequently, riparian areas have substantial effects on water quality because they help to regulate the transfer of sediment and water, and because they facilitate chemical transformations of contaminants (Naiman and Decamps 1997; Brinson et al. 2002).

This chapter reviews the transport, storage, and transformation of nutrients, metals, and synthetic organic compounds (SOCs; e.g., most pesticides) in riparian areas, and the consequences of human alterations for these ecosystem processes. The chapter concludes with a summary of the relationships between riparian setback widths and human influences on biogeochemical processes.

Effects of Human Alterations on Biogeochemical Functions

Macronutrients

Agricultural and developed lands are major sources of nitrogen and phosphorus entering streams and rivers (Jackson et al. 2001). In aquatic ecosystems, over-enrichment with phosphorus and nitrogen (i.e., eutrophication) causes a wide range of problems, including degradation of water quality for human uses (e.g., irrigation, drinking, recreation), toxic algal blooms, loss of biodiversity, and fish kills (Richter et al. 1997; Jackson et al. 2001). These detrimental effects are largely due to greatly increased growth of microbes, algae, and plants, accompanied by the decomposition of their biomass and the resulting depletion of dissolved oxygen (DO). DO is frequently the key substance in determining the extent and composition of life in water bodies (Manahan 1994). For instance, it was found to be one of the best environmental predictors of invertebrate community composition in flow-through constructed wetlands (Spieles and Mitsch 2000). Salmonids are particularly sensitive to low DO concentrations (Bjornn and Reiser 1991).

The cycles of phosphorus and nitrogen involve different mechanisms, and riparian areas affect these cycles differently. Accordingly, these cycles and the effects of human alteration are described in separate sections below.

Phosphorus

Ultimately, all phosphorus originates from the weathering of rock; it should be noted that different rock types may have substantially varied phosphate contents (Wetzel 2001). However, because it is a macronutrient, phosphorus concentrates in organisms; consequently, organic matter, fertilizer applications, wastes from concentrated animal feeding operations (CAFOs), and sewage are all important sources of the phosphorus entering streams (Jackson et al. 2001).

The availability of soluble phosphorus (i.e., phosphorus in a molecule dissolved in water) is strongly affected by pH (Wetzel 2001). Soluble phosphorus is most available at a pH of 6–7; consequently, it is most readily leached from soils of that pH range. At lower pH values, phosphorus combines readily with aluminum, iron, and manganese. At higher pH values, greater amounts of phosphate combine with calcium as calcium phosphates and apatites (i.e., minerals in which calcium and phosphorus combine with other elements). These reactions (that predominate above and below the pH 6–7 range) result in the formation of insoluble complexes and the adherence of phosphorus to the surfaces of clay particles.

In most environments (including waters with pH values of 6–7), insoluble forms of phosphorus predominate because they readily form and persist longer than soluble forms, which are rapidly taken up by microorganisms and plants or are sorbed to soil particles (Marschner 1995; Wetzel 2001). (Sorption includes absorption, adsorption, and physical interspersion or association.) Consequently, runoff is the primary means by which phosphorus enters waters, because most phosphorus is transported to streams adhered to soil particles or associated with particles of organic matter (Wenger 1999; Jackson et al. 2001; Wetzel 2001). Insoluble and sediment-bound forms of phosphorus may subsequently become soluble in streams.

Though phosphorus is readily bound to particles of clay and organic matter, soils cannot retain unlimited quantities of phosphorus. Therefore, high inputs of phosphorus could saturate binding sites in riparian soils. This saturation was suggested by the results of several studies (reviewed in Wenger 1999) where the percent of phosphorus inputs removed by newly established buffers declined over time.

Human alteration of ecosystems can affect the transport and storage of phosphorus in riparian areas through the effects of adjacent land uses, conversion of riparian areas to agricultural or developed land cover, hydrologic and geomorphic alterations, and alterations of riparian vegetation and soils. In addition to increasing phosphorus inputs, adjacent land uses can increase or concentrate overland flows, or even route them past riparian areas. For example, the Roseville Wastewater Treatment Plant adds effluent containing substantial quantities of phosphorus to Dry Creek (ECORP 2003), and this effluent enters the stream without ever passing through the soils of a riparian area. Such alterations limit opportunities for phosphorus to sorb to particles of clay and organic matter in the soil. Similarly, drainage tiles and ditches also reduce phosphorus retention by moving flows rapidly through riparian areas. Conversion of riparian areas to agricultural or developed land uses reduces the size of riparian areas, and thus reduces the residence time of flows and the capacity of the riparian area for retaining phosphorus. Direct alterations that reduce hydraulic roughness of the vegetation or soil infiltration (e.g., grazing, timber harvest) could reduce sediment deposition and the residence time of flows in the riparian area, which could in turn reduce phosphorus retention.

Nitrogen

Nitrogen cycling involves fixation of atmospheric nitrogen (N_2) into organic molecules, and the return of nitrogen to the atmosphere through denitrification (Jackson et al. 2001; Wetzel 2001). Microorganisms perform both these transformations. Nitrogen is also fixed by the high temperatures and pressures of internal combustion engines and, to a lesser extent, by lightning. The nitrogen fixed into organic molecules is stored in living organisms and the organic materials derived from them. It is a constituent of amino acids and nucleic acids, and is also a component of the animal waste products urea and uric acid, as well as other organic molecules. During decomposition, nitrogen is released to the environment in the small inorganic molecules ammonia (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). These molecules and small organic molecules (e.g., amino acids) are highly soluble, readily taken up by microbes and plants, and through denitrification are transformed to N_2 and returned to the atmosphere.

Agricultural and developed lands are major sources of the nitrogen entering streams (Jackson et al. 2001). Fertilizer applications and wastes from CAFOs are the primary sources on agricultural lands. On developed lands, nitrogen sources include septic systems, pet wastes, fertilizers applied to lawns and other landscaping, sewage systems, and some industrial sources. Erosion is also an important source of nitrogen from both agricultural and developed lands.

Unlike phosphorus, nitrogen is quite soluble and readily moves into shallow groundwater (Lowrance et al. 1984; Schnoor 1996); in many areas most nitrogen enters streams via subsurface flows (Fennessey and Cronk 1997). Denitrification is the major pathway for removal of nitrogen as this subsurface water crosses riparian areas. Plant uptake also removes nitrogen from groundwater and stores it in plant tissue (Marschner 1995; Fennessey and Cronk 1997). However, unless they are removed from riparian areas or deeply buried, plant tissues will decompose after death, releasing this stored nitrogen.

Most denitrification occurs in saturated soils (Fennessey and Cronk 1997; Jackson et al. 2001; Wetzel 2001). There, low oxygen (O_2) concentrations create a demand for NO_3^- as an electron acceptor. During aerobic respiration (the primary source of energy for the metabolic activities of animals, plants, and many microbes), oxygen is required as the terminal electron acceptor. Where limited oxygen availability hinders aerobic respiration (e.g.,, under anaerobic conditions), organisms can still derive energy from metabolic pathways that rely on other molecules as electron acceptors. In the case of denitrifying bacteria, energy is derived from organic compounds using NO_3^- instead of oxygen as the terminal electron acceptor.

Factors affecting removal of nitrates by riparian areas include the portion of flows crossing the riparian area as runoff, the rate of denitrification, and the time required for subsurface flows to cross the riparian area (Fennessey and Cronk 1997). Because surface flows cross riparian areas rapidly, little or no nitrate is removed from runoff. From subsurface flows, the amount of nitrate removed is a product of the rate of denitrification and time in the riparian area.

Rates of denitrification are governed by the following conditions.

- Nitrate concentration.
- Quantity of organic carbon.
- Degree of soil saturation.
- Activity of denitrifying bacteria.
- Temperature.
- pH.

Denitrification primarily removes nitrogen that enters riparian areas as nitrate, and low concentrations of nitrate, relative to other forms of nitrogen (e.g., organic nitrogen), can limit the rate of denitrification. For example, in one study, 76% of the nitrogen entering a riparian area was in nitrate, but only 18% of the nitrogen leaving that riparian area was in the form of nitrate (Fennessey and Cronk 1997). Compared to nitrate, a much larger fraction of nitrogen in organic compounds passes through riparian areas.

Organic matter is the substrate from which denitrifying bacteria obtain energy; consequently, the lack of a carbon source can limit denitrification. Exudates from plant roots, and the roots themselves, provide an important carbon source for soil microorganisms (Marschner 1995; Gurwick et al. 2004).

Saturated soils have higher denitrification rates than unsaturated soils because they have less oxygen availability than dry or unsaturated soils. Denitrification is a mechanism for extracting energy from organic molecules; in aerobic environments, many denitrifying bacteria will perform aerobic metabolism instead of denitrification, or will compete for carbon sources with microbes performing aerobic respiration. Aerobic respiration does not involve nitrate, and thus the rate of N_2 production decreases (Fennessey and Cronk 1997; Wetzel 2001).

The ability of denitrifying bacteria to perform denitrification depends on their abundance and the quantity of nitrate to which they have recently been exposed, which together determine the overall denitrifying activity of the microbes; temperature (which affects the rate of all reactions); and pH (Fennessey and Cronk 1997; Wetzel 2001).

The residence time of surface and subsurface water in a riparian area is as important as the rate of denitrification. Many factors affect the residence time of water in riparian areas; these include width of the riparian area, slope gradient, surface roughness, hydraulic head (i.e., the force moving water through the riparian area), and soil hydrologic connectivity (i.e., permeability) (Gordon et al. 1992; Brunke and Gonser 1997; Spruill 2000). Depending on the characteristics of the given riparian area, residence times can range from hours to months or even years. Within individual riparian areas, residence time also can vary considerably due to local concentration of flow before it enters the riparian area, heterogeneity in hydrology and topography, and the characteristic heterogeneity of the texture (and hence permeability) of riparian soils (Brunke and Gonser 1997; Fennessey and Cronk 1997).

Riparian areas typically support favorable conditions for denitrification (Fennessey and Cronk 1997; Naiman and Decamps 1997; Brinson et al. 2002). The rooting zone of riparian soils is typically saturated, and plant roots provide an organic carbon source. In addition, riparian soils support high levels of microbial activity (Fennessey and Cronk 1997; Naiman and Decamps 1997; Tufekcioglu et al. 2001; Brinson et al. 2002). Therefore, a substantial portion of the nitrates contained in subsurface flows are denitrified if they pass through the rooting zone (Pinay and Fabre 1993; Fennessey and Cronk 1997; Lee et al. 2000; Spruill 2000; Sabater et al. 2003; McKergow et al. 2004; Zegre et al. 2004).

However, not all water entering streams passes through riparian soils within the plant rooting zone, where conditions for denitrification are most favorable. For example, overland flows and deep groundwater do not pass through this zone; consequently, the riparian area may remove little nitrogen from these waters (Fennessey and Cronk 1997; Wenger 1999; Spruill 2000; Simpkins et al. 2002).

Human alterations affect the ability of riparian areas to remove nitrogen through the effects of adjacent land uses, conversion of riparian areas to agricultural and developed land cover, hydrologic and geomorphic alterations, and direct removal of riparian vegetation. Adjacent land uses can increase overland flows and nitrogen inputs, and can concentrate flows or route them past riparian areas. Increased overland flows and concentration of flows before they enter riparian areas reduces the time water spends there, and reduces their opportunity to remove nitrogen. Conversion of portions of riparian areas to developed or agricultural uses reduces the time water spends within the riparian area and hence the quantity of nitrogen removed. Artificial drainage (e.g., tile drains) also reduces the residence time of water. Flow diversions, groundwater withdrawals, and channel incision that lowers the water table below the rooting zone of riparian vegetation reduce the ability of riparian soils to remove nitrogen and the ability of plants to take up nitrogen. Riparian management that reduces infiltration, vegetation density, or the cover of woody plants can also reduce nitrogen removals by reducing flows through the plant rooting zone or by altering the density and depth of plant roots.

In western Placer County, incision of stream channels is widespread (Appendix A; Placer County 2002; ECORP 2003; EDAW 2004; Jones & Stokes 2004c), and riparian vegetation has often been reduced to a narrow discontinuous band (Appendix A; Placer County 2002). Consequently, human alterations have reduced the denitrifying capacity of these riparian areas.

Heavy Metals

Heavy metals include zinc, copper, cadmium, lead, nickel, iron, silver, chromium, and mercury. Due to their potential toxicity at low concentrations to organisms at all trophic levels, heavy metal contaminants, particularly mercury, have been identified as a problem in the Sacramento River Basin (including the Bear River in Placer County) and downstream in the Bay-Delta (CALFED 2000a). Downstream of Placer County in the Sacramento–San Joaquin Bay-Delta, relatively high (and potentially harmful) concentrations of copper, nickel, zinc, and mercury have been observed in water and in some cases in organisms (Cain and Louma 1999; Hornberger et al. 1999; CALFED 2000a). These metals can cause gill, kidney, liver, and nerve damage in fish and other aquatic organisms (Luoma et al. 1990; Schnoor 1996; Morel et al. 1998; CALFED 2000a). Because of differences in its cycling in the environment, as well as heightened concerns regarding bioaccumulation, mercury is discussed separately from the other heavy metals in this chapter.

Mercury

Mercury contamination is widespread in sediments and waters of the Sacramento Valley, including western Placer County, and downstream in the Sacramento–San Joaquin Bay-Delta. Although atmospheric deposition and inputs from developed land uses occur, mercury contamination is in large part a legacy of the

California gold mining era, when mercury was used in the gold refining process (Domagalski 1998).

The fate of mercury in the environment depends on its chemical form and the local environmental conditions (Beckvar et al. 1996). Elemental mercury, inorganic mercury, and methylmercury are the three most important forms of mercury in natural aquatic environments. Most mercury is released into the environment as inorganic mercury, which is primarily bound to sediment particles and organic substances; in this form, it may not be available for direct uptake by aquatic organisms. However, methylmercury, an extremely harmful form of mercury, is readily taken up by aquatic plants, fish, and wildlife; it has been demonstrated to bioaccumulate and transfer through the food web (Beckvar et al. 1996).

Methylmercury is formed by sulfate-reducing bacteria (Wetzel 2001). The methylation of mercury is influenced by the availability of inorganic mercury, oxygen concentration, pH, oxidation-reduction potential, presence of sulfate and sulfide, type and concentrations of complexing inorganic and organic agents, salinity, and organic carbon (Blum and Batrha 1980; Jackson 1989; Parks et al. 1989; Winfrey and Rudd 1990; Beckvar et al. 1996; Gill et al. 2002). These conditions and the biological productivity of methylating microbes are also affected by seasonal changes in temperature, nutrient supply, oxygen supply, and hydrodynamics (changes in suspended sediment concentrations and flow rates).

Methylmercury has been demonstrated to accumulate in plant and animal tissues and to transfer through the food web as contaminated food sources are consumed (Beckvar et al. 1996). Methylmercury and other associated forms of bioavailable mercury damage nervous and other tissues and cause mutations, leading to cancers and reduced survival of embryos (Birge et al. 1979; Sharp and Neff 1980; Gentile et al. 1983; Thain 1984; Morel et al. 1998; CALFED 2000a).

Sediment is the primary source of mercury entering aquatic environments in the Sacramento Valley (Beckvar et al. 1996). Correlating mercury concentrations in sediment with concentrations in biota is difficult, however, particularly for higher-trophic-level species. High concentrations of organic substances and reduced sulfur that complex with free inorganic mercury ions in sediment can reduce the availability of mercury to biota (Luoma 1977; Rubinstein et al. 1983). Many investigators report no correlation between sediment and tissue concentrations of mercury for higher-trophic-level species (Nishimura and Kumagi 1983; Jackson 1988; Rada et al. 1989b; Lindqvist 1991; Dukerschein et al. 1992). This difficulty in correlating mercury in sediment with mercury in organisms reflects the complexity of variables that affect both the methylation of mercury in surface sediments and its transfer between trophic levels (Beckvar et al. 1996).

The movement, transformation, and storage of mercury within riparian areas are particularly complex processes; the human effects on these processes are also complex. Consequently, the effects of riparian setbacks on methylmercury production are likely to vary among sites. Wide setbacks (e.g., more than 30 m

[98 ft]) would reduce inputs of mercury-laden sediments from adjacent uplands, and would reduce disturbance and remobilization of mercury-laden sediments in riparian areas. However, the saturated soils and high organic carbon content of many riparian soils provide favorable conditions for methylation of mercury; in western Placer County, such soils also likely contain some mining sediments with elevated concentrations of mercury. Therefore, riparian setbacks may reduce additional inputs of mercury to riparian areas and streams, but probably will not diminish the role of riparian areas as a source of methylmercury.

Other Heavy Metals

Heavy metals enter streams from natural and human sources. Natural sources are the dissolution of rocks and minerals in sediments. Human sources include brake pad debris (Woodward-Clyde Consultants 1994), roofing materials (U.S. Environmental Protection Agency 1978) and other urban and industrial inputs, agricultural chemicals (e.g., copper-based herbicides), historical mine tailings, and acidic mine drainage (CALFED 2000a; Paul and Meyer 2001).

Unlike SOCs, heavy metals are elements that cannot be degraded; unlike nitrate, relatively little metal is transformed into other chemical forms that volatilize into the atmosphere. Therefore, heavy metals removed from flows are merely stored in riparian areas. This storage may be transient, as when metals in overland flows rapidly cross the riparian area, or may be for prolonged periods of time, as when metals sorb to buried sediments in riparian areas.

In riparian areas and adjacent streams, metal ions may be dissolved in water (either hydrated or complexed with other ions), precipitated (i.e., in an insoluble complex), sorbed to sediment or suspended particles, or taken up by plants or microbes. With the exception of uptake by organisms, these states are reversible, and metals exist in equilibrium between them. (The concentration of metal in each state depends on its rate of conversion to other states, relative to the reverse transformation.) This equilibrium, and the concentration of metals in water, is strongly influenced by DO concentration, pH, and the abundance of organic matter (Wetzel 2001; Schnoor 1996). In anaerobic environments, metals tend to precipitate in complexes with sulfides that are generated by microbes under these conditions. Under aerobic conditions, at near neutral (i.e., pH 7) and high pH (i.e., pH greater than 7), metals tend to form precipitates (i.e., insoluble forms) with hydroxyl ions (OH^-). Therefore, solubility of metals is much greater in aerobic, acidic waters (i.e., pH less than 7). Because organic matter contains many components that complex with metals, increased concentrations of organic matter in soils and in suspended sediments reduces metal solubility.

The high biomass and organic matter content of many riparian soils contributes to the removal of metals from subsurface flows. (Riparian plants also take up metals, but they require only minute quantities of a few heavy metals as nutrients, and the root endodermis functions as a barrier that blocks most additional uptake [Marschner 1995]). Thus, riparian areas store metals that would otherwise enter streams. However, soils cannot retain unlimited quantities of heavy metals, and high inputs of metals could saturate binding sites in riparian soils. The clay and organic matter content, and pH, of riparian soils will substantially influence the quantity of metals they can retain.

The association of metals with the surfaces of sediments and suspended particles is particularly important for their transport and storage in riparian areas. Surfaces of particles, such as clays, are typically charged or polar, and these particles interact with a coating of ions and molecules removed from and reentering the surrounding water. In most environments, heavy metals tend to form surface complexes with particles, and this tendency has been described as “metals scavenging” by particles (Schnoor 1996).

Because of the insoluble precipitates and complexes with particles formed by metals, eroding sediments are the major delivery mechanism for metals into riparian areas. The high surface roughness and soil permeability of many riparian areas causes deposition of metal-containing sediments that would otherwise enter streams. However, this storage is not necessarily permanent. Metals may be subsequently leached from these transported sediments, and the sediments themselves may be subsequently eroded or moved by floodwaters. Riparian soils cannot retain an unlimited quantity of heavy metals (similar to soil limitations regarding phosphorus retention), and high inputs may saturate the available binding sites.

Human alterations can affect the transport and storage of heavy metals in riparian areas through the effects of adjacent land uses, conversion of riparian areas, direct hydrologic and geomorphic alterations, and direct alterations of riparian vegetation. In addition to increasing metal inputs, human alterations of adjacent lands (e.g., acid mine drainage) can increase the acidity of waters and the leaching of metals from riparian sediments. Adjacent land uses can also increase or concentrate overland flows, or even route them past riparian areas. These alterations limit opportunities for heavy metals to sorb to particles of clay and organic matter in the soil. Similarly, drainage tiles and ditches reduce metal retention by moving flows rapidly through riparian areas. Conversion of riparian areas to agricultural or developed land uses reduces the size of riparian areas, and consequently reduces the residence time of flows and the capacity of the riparian area for retaining heavy metals. Direct alterations that reduce hydraulic roughness of the vegetation or soil infiltration could reduce sediment deposition and the residence time of flows in the riparian area, also reducing metal retention.

Synthetic Organic Compounds

SOCs include most pesticides and herbicides and a wide variety of chemicals used in industry. Many of these artificial compounds persist in the environment for prolonged periods (in some cases for decades), and some (e.g., polychlorinated biphenyls [PCBs]) bioaccumulate in animal tissues (Schnoor 1996). (Use of some of the most persistent molecules has been banned, but the compounds have remained in the environment.)

Pesticides (including diazinon, carbofuran, and chlorpyrifos), herbicides, solvents, and other SOCs are frequently washed into the Sacramento Valley's river systems during irrigation, by winter storms, and through urban runoff (Kuivila and Foe 1995; MacCoy et al. 1995; Domagalski 1996). These compounds can have direct and indirect harmful effects on soils and aquatic organisms including microorganisms, invertebrates, and vertebrates (CALFED 2000a). For example, diazinon, an organophosphate insecticide used for many agricultural applications, and until recently for urban applications as well, is highly toxic to birds, terrestrial insects, aquatic invertebrates, soil microbes, and fish (Ingham and Coleman 1984; Stone and Gradoni 1985; Mackenzie and Winston 1989; Robertson and Mazzella 1989; Turner 2002). Application of this insecticide coincides with the rainy season in California, resulting in runoff discharges into streams and rivers. Consequently, in tributaries of the Sacramento River (including the Bear River in Placer County), peak values of diazinon can exceed state or federal water quality standards by an order of magnitude or more (Turner 2002).

The SOCs in streams and rivers may come from point and nonpoint sources, release of materials stored in sediments, illegal dumping, and accidental spills. Applications of pesticides and herbicides to plants and soils in agricultural and developed lands are particularly important sources of SOCs. When applied by field equipment, aerial drift may distribute them for several meters beyond the site of application (de Snoo and de Wit 1998); when these compounds are applied by airplanes, drift may extend much further (tens to hundreds of meters).

In the environment, SOCs can volatilize (i.e., disperse into the atmosphere), dissolve in and be transported by water, adsorb to soil, bioaccumulate in animals, and degrade. The fate of these compounds is determined by their chemical properties, especially their size and solubility in water. Synthetic organic compounds vary widely in size and polarity. Many SOCs contain highly polar alcohol, organic acid, and ionic groups that increase their polarity, and increase their solubility in water. However, other SOCs are essentially non-polar; these are generally insoluble. For example, the solubility in water of PCBs and dichlorodiphenyltrichloroethane (DDT) is low (approximately 10^{-2} $\mu moleL^{-1}$); that of chlorpyrifos is higher (about 1 $\mu moleL^{-1}$); whereas the solubility of industrial solvents such as toluene and tetrachloroethylene is very high ($>10^{3}$ $\mu moleL^{-1}$).

The smallest SOCs (e.g., organic solvents) are those most prone to volatilize. However, larger molecules that are relatively insoluble in water also volatilize at moderate rates (Schnoor 1996).

SOCs also sorb to particles of soil and organic matter. This sorption occurs through electrostatic attractions, ionic bonding, or physical intermingling (e.g., the dissolution of a non-polar molecule among particles of organic matter). However, stronger and less reversible chemical bonds also may form. The tendency of an SOC to sorb to sediment is negatively related to its solubility in water (i.e., molecules with lower solubility in water have greater propensity to sorb to sediment). The sorbed molecules of SOCs attach primarily to clays and particles of organic matter, and the sorption of SOCs increases substantially with the concentration of organic matter in the sediment (Schnoor 1996; Neitsch et al. 2002).

The accumulation of SOCs in organisms (i.e., bioaccumulation) represents the net balance resulting from uptake across gill and skin, ingestion from food, metabolic degradation, and excretion. The SOCs most prone to bioaccumulate are the relatively non-polar, hydrophobic molecules (e.g., DDT, PCBs, chlordane) that tend to sorb into membranes and fatty tissues (Schnoor 1996). Typically, these are the same molecules that tend to sorb to sediment.

SOCs can be degraded (changed into other molecules) through the absorption of light energy (photodegradation), by reacting with water or chemicals in water or soil (chemical degradation), or by microorganisms (biodegradation). With the exception of photodegradation, these processes occur most rapidly in soil (Brinson et al. 2002; Neitsch et al. 2002). Biodegradation occurs because microorganisms use SOCs as food sources; they obtain energy stored in the chemical bonds of SOCs through a series of oxidation-reduction reactions, ultimately breaking the SOCs down to carbon dioxide and water. Microbes also mediate other transformations of SOCs (Schnoor 1996). Rates of degradation of SOCs vary over a wide range (Schnoor 1996). Chemical degradation of molecules dissolved in water can reduce the concentration of some SOCs by half within minutes, while other SOCs require years before concentrations are halved. Photodegradation can break down more than 99% of dissolved Carbaryl in a month, but does not eliminate 1% of DDT in a year. For any given SOC, biodegradation rates vary with the environmental conditions listed below.

- Temperature.
- Concentration of oxygen.
- Nutrient availability.
- Microbial population density or biomass concentration.
- Acclimation of the microbial flora to the SOC.

All these factors affect the activity of microbes that perform biodegradation. Riparian areas are considered to support high rates of biodegradation because they typically contain a range of oxygen and nutrient availability, and they support dense, active populations of microorganisms (Fennessey and Cronk 1997; Naiman and Decamps 1997; Tufekcioglu et al. 2001; Brinson et al. 2002).

Overall, the degradation of SOCs in riparian areas depends not only on degradation rates but also on the infiltration of water and associated SOCs into the soil and the time required for water to cross the riparian area. Because overland flow (i.e., runoff) crosses riparian areas rapidly, little or no degradation or storage occurs (Neitsch et al. 2002; Popov and Cornish 2004). Factors affecting the passage of subsurface flows through a riparian area include its width, hydraulic head, and hydrologic conductivity (Fetter 1994; Brunke and Gonser 1997).

The degradation and storage of SOCs in riparian areas is entirely dependent on human alterations because they are the sole source of SOCs. In addition to generating inputs, human alterations also affect the degradation and storage of SOCs in riparian areas by converting these areas to other land-cover types; reducing infiltration of water in riparian areas and adjacent uplands; and lowering groundwater levels through groundwater withdrawals, flow diversions, and stream channel incision. All these alterations reduce the quantity of SOCs passing through riparian soils and the time they remain there. Alterations that concentrate overland flows, or that reduce the hydraulic roughness of riparian vegetation, can also reduce the deposition of SOCs associated with suspended sediment. In western Placer County, incision of stream channels and loss of riparian vegetation have reduced the ability of riparian areas to degrade SOCs.

Relationships Between Effects and Setback Width

A substantial quantity of research has been conducted worldwide on the biogeochemical functions of riparian areas, the effects of human alterations on those functions, and the benefits of managed buffers between streams and areas of timber harvest, agricultural activities, and development (Correll 2003). This research strongly supports the conservation and management of riparian areas and adjacent uplands for water quality benefits, and it has identified the factors affecting riparian functions. Accordingly, this research provides justification for riparian setbacks and some information to guide their planning and design. Nonetheless, current understanding is not sufficient to reliably determine the exact effects that different width buffers will have on biogeochemical functions (and stream water quality). Several computer models have recently been developed that could be used to evaluate the consequences of different width setbacks (Lowrance et al. 2000; Dallo et al. 2001; Zhongwie and Wong 2004). However, these models have several deficiencies: they have not been tested under a range of conditions; they have several unresolved issues regarding their accuracy; and they are currently costly to apply (Inamdar 2004).

The most important factors affecting biogeochemical functions in riparian areas are listed below.

- Loadings from adjacent uplands.
- Partitioning of runoff between overland and subsurface flow.
- Distribution (i.e., spatial concentration) of overland flow.
- Depth of shallow groundwater.
- Time that water resides in the riparian area or buffer (i.e., residence time).
- Quantity of sediment eroded and transported to riparian areas.
- Redistribution of deposited sediment by subsequent floodwaters.

The width of riparian setbacks can affect several of these factors, and can consequently affect the biogeochemical functions of riparian areas. First, the width of a setback determines the distance between stream waters and sources of macronutrients, metals, and SOCs. A wide riparian zone increases infiltration (and subsurface flows), rates of sediment deposition, and the time required for materials to reach a stream. Thus, greater setback widths tend to increase the storage and removal of materials en route to streams. Second, the area of sources for macronutrients, metals, and SOCs is reduced by wider setbacks because more land is retained in natural vegetation. Third, if a riparian setback extends beyond the stream's active floodplain, then sediments and associated contaminants will be stored, at least in part, outside the active floodplain, where they are less likely to be carried into streams by floodwaters.

Researchers have documented substantial reductions in stream loadings of macronutrients, metals, and SOCs due to riparian areas or buffers ranging in width from several to more than a hundred meters. (Castelle et al. 1992; Fennessey and Cronk 1997; Wenger 1999; Brinson et al. 2002.) Reductions resulting from a very narrow riparian area (e.g., 6 m [20 ft]) in one study may be comparable to reductions in a much wider riparian area (e.g., 30 m [98 ft]) in another study. This variability reflects both differences in site attributes that affect movement, transformation, and storage of these materials, as well as variability in the methods of researchers.

Overall, the most significant factors causing variation in the biogeochemical functions of riparian areas are hydrologic conditions (e.g., the depth of subsurface flows); climate and vegetation attributes seem to cause lesser effects (Fennessey and Cronk 1997; Simpkins et al. 2002; Sabater et al. 2003). Nonetheless, California's Mediterranean climate may reduce a setback's effectiveness relative to a setback of similar width in other climates. In northern California, because rainfall is concentrated during the winter months and evapotranspiration is low at that time, rain frequently falls on saturated soils, and overland flows are consequently greater than they might be under a different climatic regime.

Variation in the results of relevant research is often due to differences in the types of sites and the range of conditions included in the study. For example, many studies are conducted in small-scale plots with simulated rainstorms. The results of such short-term studies under a narrow range of conditions often indicate greater effectiveness of narrow buffers or setbacks than do the results of longer-term, larger-scale studies (Castelle et al. 1992; Davies and Nelson 1994; Fennessey and Cronk 1997; Wenger 1999; Lee et al. 2000; McKergow et al. 2004; Zegre et al. 2004). Similarly, actively managed buffers, such as tilled and planted borders of agricultural fields, are generally more effective at narrower widths than are unmanaged setbacks; appropriately, many of the recommendations for narrower setbacks are intended for actively managed areas (Lowrance et al. 2002).

Recommended Setback Width to Conserve Biogeochemical Functions

For the purpose of long-term conservation of biogeochemical functions, the project team recommends that riparian setbacks include the entire active floodplain, regardless of the current extent of riparian vegetation on that surface, and that an additional 30-m (98-ft) buffer be included in the setback.

For effective long-term conservation of riparian functions, setback widths should be sufficient to retain macronutrients, metals, and SOCs from the concentrated flows and infrequent events (e.g., intense rain on saturated soils) that transport a substantial portion of the sediment and materials to riparian areas. This criterion requires a setback of moderate width. Consequently, for the purpose of long-term conservation, though widths from several to more than a hundred meters have been recommended, setbacks of 20–30 m (66–98 ft) have been recommended most frequently (Castelle et al. 1992; Johnson and Ryba 1992; McCauley and Single 1995; Fennessey and Cronk 1997; Herrone and Hairsine 1998; Wenger 1999; Lowrance et al. 2002; Environmental Law Institute 2003; Lee et al. 2004).

It is important to note that setbacks do not ameliorate many effects of human alterations on biogeochemical functions. Not all inputs (of macronutrients, metals, SOCs, and other contaminants) to streams will pass through riparian soils (e.g., deeper groundwater flows, stormwater, and agricultural drainage that crosses in pipes or ditches). Moreover, riparian setbacks will not retain all inputs of fertilizers, heavy metals, pesticides, and other contaminants that pass through them. In addition, high levels of inputs may cause the effectiveness of setbacks to may diminish over time. Therefore, other measures that address the upland sources of macronutrients, metals, SOCs, and other contaminants are necessary.

Chapter 4
Salmonid Habitat Functions

Overview

Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss irideus*) are anadromous fishes that spend a major portion of their lives in the Pacific Ocean. Maturing adult steelhead and Chinook salmon migrate from the ocean to spawn in Central Valley rivers and creeks, including those of western Placer County. After rearing in these rivers, the juveniles migrate back to the Pacific Ocean.

Salmonids occupy the freshwater systems from the Sacramento–San Joaquin Delta (Delta) to stream headwaters, depending on the streams' accessibility to migrating fish and the availability of spawning and rearing habitat within them. Not only are salmonid habitat functions valued directly, but they also provide an indicator of human effects on other components of these aquatic ecosystems. This chapter describes salmonid habitat functions and how human alterations affect those functions. It concludes with a summary of the relationships between riparian setback width and human effects, and offers the project team's recommendation for setback widths to conserve salmonid habitat functions.

Effects of Human Alterations on Migration

Shallow water depth, high water velocity, and physical barriers may impede salmonid passage through spawning streams. Human alterations affect each of these potential impediments to migration.

Water Depth

In general, water depth greater than 0.3 m (1 ft) is needed to allow passage of adult and juvenile Chinook salmon and steelhead (California Department of Fish and Game 2001; National Marine Fisheries Service 2001). However, this minimum depth may be a somewhat conservative estimate, because Chinook salmon and steelhead can pass through short sections of water that are less than 0.3 m (1 ft) deep (Thompson 1972 *in* Bjornn and Reiser 1991).

Low streamflows and shallow water depths may delay or block migrating salmonids' access to upstream spawning habitats, expose adult fish to water temperatures detrimental to individual survival, and reduce the fecundity of females (i.e., egg viability). Delayed passage of adults may also delay spawning and extend incubation of eggs and rearing of juveniles into months when warmer water temperatures predominate. The result may be reduced egg and juvenile survival and reduced productivity in that year (i.e., year class production).

Low streamflows can also affect juvenile migration. Like the requirements for adult salmonid passage, water depth greater than 0.3 m (1 ft) is necessary for passage of juvenile Chinook salmon and steelhead (California Department of Fish and Game 2001; National Marine Fisheries Service 2001). Delayed or blocked passage of juveniles may prevent access to downstream rearing habitat and increase their exposure to warm water temperatures, entrainment in diversions, and predation. The resulting decrease in survival and growth rates reduces year class production and potentially reduces adult abundance in subsequent years.

Relatively shallow flow in combination with physical barriers and high water temperatures can cause fish to fatigue as they migrate upstream; these cumulative effects may lower the survival and reproductive success of individual fish (Gallagher 1999). For these reasons, long stretches of river with maximum depths near 0.3 m (1 ft) may be barriers to migration. Other factors interacting with the effects of depth include cover and suitable resting areas (e.g., deep pools).

Flow rates may affect travel time for juvenile salmonids. Travel time for juvenile Chinook salmon and steelhead generally decreases with increasing flow and water velocities. Faster travel times may reduce exposure to predation and facilitate movement of smolts to the ocean (Berggren and Filardo 1993).

Vertical Drops

In addition to adequate depth and velocity, vertical drops should not exceed the leaping abilities of Chinook salmon and steelhead. The ability to jump vertical drops is greatly affected by staging pool depth, jump angle, and the horizontal distance of the leap (Powers and Orsborn 1985; Reiser and Peacock 1985). The ratio of staging pool depth to barrier height should be at least 1.5 (Stuart 1962; U.S. Forest Service 1977; Robison et al. 1999). Although the conservative vertical limit for adult fish is 1.4 m (4.5 ft) for steelhead and 0.9 m (3 ft) for Chinook salmon, passage is best facilitated by drops of 0.3 m (1 ft) or less. For juvenile salmonids, downstream migration is facilitated by drops of 0.15 m (0.5 ft) or less (National Marine Fisheries Service 2001).

Water Temperature

Warm temperatures and low DO concentrations may impede salmonid migration. Temperatures warmer than 13º Celsius (C) (55ºFarenheit [F]) have caused mortality of female adult Chinook salmon prior to spawning, and migration was blocked when water temperature reached 21ºC (69.8ºF) in the Delta (Andrew and Green 1960 *in* Raleigh et al. 1986; Hallock 1970 *in* McCullough 1999). In the Columbia River, a temperature of 21ºC (69.8ºF) was lethal to steelhead acclimated to a river temperature of 19ºC (66.2ºF). The response to warm temperatures may be complicated by low DO concentrations. In the Delta, adult Chinook salmon avoided temperatures warmer than 19ºC (66ºF) when DO was less than 5 milligrams per liter (mg/l) (Alabaster and Hallock 1988, 1970 *in* McCullough 1999).

Discussion of Effects

Construction of dams and other barriers, such as temporary diversion structures, are the most significant human alterations affecting migration and causing the loss of salmonid habitats (Yoshiyama et al. 2001). These barriers prevent Chinook salmon and steelhead migration to the higher foothill reaches of many streams in the Sacramento Valley. The alteration of flows, temperatures, and water quality below major reservoirs may also interfere with salmonid migration.

In western Placer County, dams are considerable impediments to fish passage. There are approximately thirty dams on western Placer County's streams (DWR 2002; Placer County 2002; Bailey Environmental 2003). While some of these allow fish passage under many flow conditions, others (e.g., Cottonwood Dam on Miners Ravine) are more substantial barriers.

Water control structures, road crossings, and culverts constrain flows and can create high water velocities. Culverts are characteristically uniform and designed to optimize flow efficiency, often resulting in high velocities. The velocity a fish can overcome in moving through a culvert depends on its length; as culvert length increases, flow velocities must decrease to permit fish passage. In general, water velocity should be less than 1 meter per second (m/sec) (3 feet per second [ft/sec]) for any culvert more than 30 m (98 ft) long and less than 1.5 m/sec (5 ft/sec) for culverts less than 30 m (98 ft) long (California Department of Fish and Game 2001). In western Placer County, roads cross streams at dozens of locations, and the culverts under a number of these roads are partial barriers, particularly at low flows (DWR 2002; Placer County 2002; Bailey Environmental 2003).

Surface water diversions and management of water releases from reservoirs can affect migration and increase mortality of juvenile salmonids by creating warm water temperatures. Diversions also can cause direct effects such as migration delay, injury, and mortality resulting from entrainment, impingement, and predation (National Marine Fisheries Service 1994). Entrainment occurs when fish move with the diverted flow into a canal or turbine; in most cases, entrained organisms do not survive. Impingement occurs when individual fish come in contact with a screen, a trashrack, or debris at the intake. Contact causes bruising, loss of scales, and other injuries. Fish mortality can result if impingement is prolonged, repeated, or occurs at high velocities. In addition, intakes increase predation by stressing or disorienting prey fish and by providing habitat for fish and bird predators (National Marine Fisheries Service 1994).

The proportion of a population that can become entrained or impinged in diversions depends on the location, timing, duration, and volume (relative to total flow) of the diversion relative to the distribution, abundance, and behavior of each species' life stage. Diversions in the Sacramento River Basin affect juvenile Chinook salmon and steelhead (U.S. Fish and Wildlife Service 1995). In addition to the possibility of entrainment at unscreened diversions, juvenile salmonids can be impinged against screens by fast-moving water, or they can pass through screens that are not designed to screen out salmonid fry and other small fish. Western Placer County's dams are associated with water diversions. Most of these diversions are unscreened, and thus entrainment can occur.

Effects of Human Alterations on Spawning Habitat

Salmonids lay their eggs in streambed gravels. The fish create depressions in the gravel, deposit and fertilize their eggs, and then bury the eggs with gravel. The resulting gravel nest is called a redd. The quality of spawning habitat is influenced by water temperature and depth, flow velocity, and substrate.

Water Temperature

Chinook salmon eggs and larvae require temperatures between 4ºC and 12ºC (39.2ºF and 53.6ºF) for maximum survival (Myrick and Cech 2001). Survival of eggs was less than 50% when temperature is warmer than 16ºC (60.8ºF) (Alderice and Velsen 1978). Optimal water temperatures for steelhead spawning and incubation are similar to those of Chinook salmon; they fall between 3.9ºC and 11.1ºC (39ºF and 52ºF) (Myrick and Cech 2001). Steelhead eggs subjected to temperatures warmer than 15ºC (59ºF) are prone to increased mortality.

Water Depth and Velocity

Water depth and flow velocity are factors that influence spawning habitat selection for Chinook salmon and steelhead. Minimum water depths at redd areas vary with fish size and water velocity, because these variables affect the depth necessary for successful digging; the water should be sufficiently deep to cover the fish (Healey 1991). In general, suitable spawning gravels are covered by flows at least 0.25 m (0.8 ft) deep and with velocities between 0.25 m and 1.2

m/sec (0.8 and 3.8 ft/sec) (Bjornn and Reiser 1991; Railegh et al. 1986). Reduced flows during incubation periods may cause mortality through desiccation of redds, or through reduced water circulation resulting in low DO, accumulation of metabolic waste, and increased incidence of disease.

Substrate

Although the suitability of gravel substrates for spawning depends largely on the species and individual fish size, a number of studies have determined substrate sizes that represent the most suitable conditions. Generally, Chinook salmon require substrates of approximately 0.3–15 cm (0.1–5.9 inches), whereas steelhead prefer substrates no larger than 10 centimeters (4 inches) (Bjornn and Reiser 1991).

The eggs depend on water flow through spawning gravels to supply oxygen for the developing embryos. Oxygen is supplied by the water flowing through the area of the gravel bed with the eggs (i.e., the redd). Flow rates and the concentration of oxygen in the flowing water effectively determine the DO available to eggs and fry in the redd.

The velocity of the water and the permeability of the surrounding gravels together determine the rate at which water flows through a redd. Gravel beds consisting of smaller-sized particles have lower permeability (greater resistance) to water flow than do gravel beds consisting of larger-sized particles. Therefore, the velocity of water through a redd slows as particle size decreases.

Discussion of Effects

Throughout the Central Valley, including Placer County, human alterations (i.e., changes in sediment supply and transport) have substantially reduced the extent of suitable spawning gravel for salmonids (Jones & Stokes 2004c). Along most Central Valley rivers and streams, sediment supply and transport have been altered by hydraulic mining, levees, land use changes, gravel mining, dam construction, and water diversions (CALFED 2000b). Currently, managed forest lands, roads, construction, and developed and agricultural lands contribute substantially more sediment than do areas of natural vegetation (Charbonneau and Kondolf 1993). In the lower portions of watersheds, most of this sediment is of fine materials (less than 2 mm [0.08 in] in diameter). On most rivers and streams, dams block the transport of coarser materials from the upper portions of watersheds, while gravel mining has removed coarse materials from downstream floodplains and channels. As a consequence of these changes, spawning habitats for Chinook salmon and steelhead have been reduced.

The addition of fine sediments into streams and streambeds can decrease the quality and quantity of spawning habitat by reducing the permeability of spawning gravels and thus reducing the flow of water and oxygen to eggs, which leads to direct mortality of eggs and fry, physiological stress, and impediments to the movement of fry from the redd (Gibbons and Salo 1973; Tappel and Bjornn 1983, Sigler et al. 1984; Raleigh et al. 1986; Lloyd et al. 1987; Reynolds et al. 1989; Waters 1995; Ligon et al. 2003). In western Placer County, gravel beds currently have high concentrations of fine sediments that reduce suitability for spawning (Jones & Stokes 2004b).

Spawning habitats are also affected by human alterations of riparian vegetation. The loss of riparian vegetation has contributed to increased water temperatures and reduced quality of spawning habitat along many Central Valley rivers and streams, including those in western Placer County (CALFED 2000b; Jones & Stokes 2004b). Reduced flows may allow riparian vegetation to establish on river bars and channels where establishment and survival were not previously possible because of scouring or prolonged submergence under unregulated flow regimes (Pelzman 1973). This encroachment of vegetation stabilizes sediments and confines the channel, contributing to a reduction in salmonid spawning habitat.

Effects of Human Alterations on Rearing Habitat

Multiple environmental conditions, food resources, and interactions among individuals, predators, and competitors all influence rearing habitat quantity and quality and the productivity of streams (Bjornn and Reiser 1991). Water temperature and velocity, cover, and inundation of floodplains are particularly important factors influencing salmonid rearing habitats.

Water Temperature

Water temperature has a strong affect on juvenile salmonids, and rearing success deteriorates at water temperatures above 20ºC (68ºF) (Raleigh et al. 1984; Myrick and Cech 2001). Myrick and Cech (2001) observed maximum juvenile growth rates at water temperatures between 17ºC and 20ºC (62.6ºF and 68ºF) and at 19ºC (66.2ºF), for steelhead and Chinook salmon, respectively. Rich (1987) found that juvenile Chinook salmon from the Nimbus State Fish Hatchery died before the end of the experiment when reared at 24ºC (75.2ºF). Steelhead juveniles can be expected to show significant mortality at temperatures exceeding 25ºC (77ºF) (Raleigh et al. 1984; Myrick and Cech 2001).

Water Velocity

Water velocity is of particular importance in determining where juvenile salmonids occur, because it determines the energetic requirements of fish for maintaining position and the amount of food delivered to a particular location. Juvenile salmonids tend to select positions that maximize access to food and minimize energy expenditures, but these positions can be altered by interaction with other fish and the presence of cover (Shirvell 1990). The water velocity preferred by salmonids varies with size of the fish; larger fish occupy areas of higher velocity and greater depth than small fish, potentially gaining access to abundant food and avoiding predatory birds (Bjornn and Reiser 1991; Jackson 1992). Griffith (1972 *in* Raleigh et al. 1984) found water velocities of 0.10–0.22 m/second (sec) (0.32–0.72 ft/sec) to be associated with occurrence of rainbow trout. Sheppard and Johnson (1985) found similar results for juvenile steelhead; they measured velocities of 0.12–0.24 m/sec (0.40–0.80 ft/sec). Bovee (1978 *in* California Department of Fish and Game 1991) reported water velocities of 0.18–0.37 m/sec (0.6–1.2 ft/sec) as the preferred range for juvenile rainbow trout and steelhead.

Cover

Instream cover (e.g., undercut banks, downed trees, other woody debris) is important for juvenile rearing. The addition of cover increases spatial complexity and may reduce predation of juvenile fish. The abundance of food, suitable physical conditions, and the presence of competitors and predators determine cover value. Fine-textured instream woody material provides the hydraulic diversity necessary for selection of suitable velocities, access to drifting food, and escape refugia from predatory fish. An area of cover less than 15% of the total habitat area is likely inadequate for juvenile salmonids (Raleigh et al. 1984).

Shaded riverine aquatic (SRA) cover is important to juvenile Chinook salmon and steelhead because it provides high-value resting and feeding areas and protection from predators. Riparian vegetation not only provides woody debris for instream cover, but also filters sediments, inputs organic matter, modifies channel pattern and geometry, creates SRA cover, and provides habitat for aquatic invertebrates eaten by salmonids. For these reasons, stream sections shaded by riparian vegetation (in contrast to sections characterized by denuded banks) provide important rearing and resting areas for adult Chinook salmon and steelhead migrating upstream (Raleigh et al. 1984, 1986; Slaney and Zaldokas 1997; Haberstock 1999; CALFED 2000b). Woody material is important not only because it provides instream cover, but also because it affects geomorphology and facilitates the creation of pools for holding juvenile salmon during high flow events (Larson 1999; Macklin and Plumb 1999). Shade reduces daily temperature variability and maximum temperature, maintains DO, and may help maintain base flows during dry seasons (Slaney and Zaldokas 1997; Whitting 1998; Haberstock 1999; CALFED 2000).

Floodplain Habitat

Seasonally inundated floodplains, though they provide habitat for both native and nonnative fish species, are particularly important to native species (Moyle et al.

2000). Many native fish species, including salmonids, are dependent on or benefit from inundated floodplains. Floodplains function as nursery areas, refuges from low water temperatures in early spring and winter, and refuges from high water velocities during high flow periods (Turner et al. 1994). Inundated floodplains also provide high food abundance, a range of water temperature conditions, and increased water clarity that may increase growth and survival rates (Sommer et al. 2001a, 2001b). Inundated floodplains of the Sacramento River and its tributaries may also provide high-quality organic nutrients to the Bay-Delta, benefiting estuarine species.

Discussion of Effects

Human alterations have affected rearing habitat by reducing water quality, removing riparian vegetation, hydraulically isolating floodplains, and altering flows. The introduction of nonnative predatory fish species has also detrimentally affected juvenile rearing. These alterations have all contributed to the loss of rearing habitat in western Placer County.

Adjacent agricultural and developed land uses are sources of contaminants and sediment (e.g., macronutrients, pesticides, and heavy metals) that reduce water quality. These effects on water quality are described in the chapter dealing with biogeochemical functions.

In addition to physically affecting salmonids, contaminants and sediments can cause changes in macroinvertebrate communities. These changes in turn can affect food available to foraging fish (Waters 1995). Such changes may have occurred in the streams of western Placer County, because in all six streams for which data are available, macroinvertebrate communities are dominated by species moderately to highly tolerant of pollution (Bailey 2003).

Researchers have found that elevated concentrations of suspended sediment can cause direct mortality of fry, fingerlings, and juvenile salmonids (Sigler et al. 1984; Lloyd et al. 1987; Reynolds et al. 1989). Sublethal effects include avoidance of sediment-laden areas, reduced feeding and growth, respiratory impairment, reduced tolerance to disease and toxicants, and physiological stress (Waters 1995).

The loss of riparian vegetation and SRA cover results from conversion of riparian areas to other land uses, adjacent gravel mining, placement of bank protection (e.g., riprap), grazing, and other direct removals (e.g., due to levee maintenance). It also is a consequence of hydrologic and geomorphic alterations, such as flow reductions and incision. Because riparian vegetation affects not only stream water temperature, but also cover, food resources, habitat complexity, and geomorphic processes (e.g., pool formation, bank stability), its loss substantially degrades rearing habitat. In western Placer County, conversion to developed or agricultural land-cover has removed extensive areas of riparian vegetation (Jones & Stokes 2004a, 2004b), and remaining vegetation is often in narrow bands with a discontinuous cover of trees (Appendix A).

Water diversions cause broad effects on stream ecosystems that can reduce the quality of rearing habitat. Water diversions affect fish, aquatic organisms, sediments, salinity, streamflows, habitat, foodweb productivity, and species abundance and distribution (National Marine Fisheries Service 1994). Some diversions have screens that exclude larger organisms such as most adult fish, but eggs, larvae, invertebrates, plankton, organic debris, and dissolved nutrients are important components of the lower trophic levels that may be lost to diversions. Reductions at the lower trophic levels can result in reduced food supplies and have secondary impacts on all higher trophic levels, affecting the overall foodweb. In western Placer County, there are over two dozen water diversions, and most of these are unscreened (DWR 2002; Placer County 2002; Bailey Environmental 2003; Jones & Stokes 2004b).

Human alterations affecting hydrologic and geomorphic processes can reduce rearing habitat on floodplains. (The effects of human alterations on hydrologic and geomorphic processes are described in detail in the chapter on hydrologic and geomorphic functions.) These alterations include water diversions, groundwater withdrawals, dams, levees, bank protection, and changes in land cover. Due to human alterations, in western Placer County, stream channel incision has reduced the area of rearing habitat on floodplains.

In addition to inundating floodplains, streamflow has several effects on the rearing capacity of streams. Predation may increase during low flows, particularly during downstream migration of juveniles. Higher flows result in faster outmigration, reduced water clarity, and cooler water temperature, all contributing to reduced predation (U.S. Fish and Wildlife Service 1996). Both flow and depth affect travel time for juvenile salmonids. Faster travel time may reduce exposure to predation and facilitate movement of smolts to the ocean (Berggren and Filardo 1993).

Flow alterations have a major effect on the water temperatures of Sacramento Valley streams. For rivers and larger streams, reservoir operations (i.e., the timing, temperature, and magnitude of reservoir releases, as well as total reservoir storage) are among the most important influences on water temperatures. Agricultural and municipal diversions reduce river flow and potentially increase temperatures during summer months (Myers et al. 1998; Myrick and Cech 2001), and the elevated temperatures of irrigation return flows can also affect instream water temperatures (U.S. Fish and Wildlife Service 1995). Water temperatures that are marginal or unsuitable for rearing of juvenile salmonids frequently occur along most streams in western Placer County (Bailey 2003; Jones & Stokes 2004b).

Streamflow also affects the concentration, and consequently the detrimental effects, of contaminants. For example, experimental studies indicated that contaminants in agricultural return flow from the west side of the San Joaquin Valley had no detrimental effects on the growth and survival of juvenile Chinook salmon when the return flows were diluted by 50% or more with San Joaquin River water (Saiki et al. 1992).

High pesticide concentrations may affect aquatic invertebrates (Brown et al. 2000). Adult and larval aquatic macroinvertebrates are a major food source for juvenile Chinook salmon, and a loss of invertebrate production could have an effect on juvenile salmonid production (Brown and May 2000); however, the extent of this effect has not been quantified.

Rapid fluctuations in flows can cause the stranding of juvenile and adult anadromous fish and the dewatering of redds. Fish can become stranded in borrow areas, the floodplain, shallow nearshore areas, side channels, and deep areas in the active stream channel when water levels change quickly.

Although adult fish do become stranded, juvenile fish are more vulnerable to stranding. Fry are poor swimmers and tend to stay in shallower water along the edges of streams and rivers or in side channels (Phinney 1974; Woodin 1984; Hunter 1992). Juvenile fish are not as able to follow receding waters back to the river (U.S. Fish and Wildlife Service 1995b). Also, redd dewatering can occur when flows decline while eggs are incubating.

Factors such as the total drop in stage, the lowest water level attained, the frequency of flow reductions, and the rate of change in flow affect fish stranding rates. In an episode of flow reduction, the greater the total drop in stage, and the lower the lowest flow attained, the more likely it is that side channels and shallow ponds in the floodplain will be isolated from flow and that gravel bars where redds may be located could be exposed (Hunter 1992). Frequent flow fluctuations result in cumulative stranding (U.S. Fish and Wildlife Service 1995; Bauersfeld 1978), and the faster the rate of change in flow, the more likely fish are to become stranded. Olsen (1990) found that ramping rates of less than 2.5 cm per hour (1 inch per hour) were needed to protect steelhead fry on the Sultan River in Washington State.

Relationships Between Setback Width and Effects of Human Alterations

The width of riparian setbacks directly affects the integrity of geomorphic processes that sustain salmonid habitats, the area of floodplain rearing habitat, and the extent of riparian vegetation providing SRA cover and inputs to the aquatic ecosystem. Setback width also influences inputs of sediment and contaminants from adjacent uplands; these inputs are described in other chapters (Chapters 2, 3, and 5) of this report.

Structures, developed land uses, and most agricultural land uses within the active floodplain detrimentally affect salmonid habitat functions. Thus, to conserve salmonid habitat functions, setback widths should be sufficient to include the active floodplain and to buffer the active floodplain from detrimental effects that may result from adjacent land uses.

All riparian vegetation within the active floodplain contributes inputs to the aquatic ecosystem. These inputs are greatest from vegetation immediately adjacent to the stream channel, and shade is only provided by vegetation within a distance determined by stream orientation, tree height, and topography. In some cases (e.g., topographically confined or incised reaches), the vegetation affecting streams is outside the active floodplain. One tree height (i.e., potential maximum tree height on that site) has often been used as an approximation of the width of the zone alongside streams that provides effective shading and inputs (e.g., large woody debris) to the channel (Rhodes et al. 1994), although vegetation further from streams can still, in the proper circumstances, provide some shade. This distance (i.e., potential maximum tree height) is roughly 20 m (66 ft) to as much as 30 m (98 ft) in western Placer County, based on the observed and potential heights of mature Fremont's cottonwoods, valley oaks, and other tree species (Hickman 1993; Stuart and Sawyer 2001).

Recommended Setback Width to Conserve Salmonid Habitat Functions

For the purpose of long-term conservation of salmonid habitat functions, the project team recommends that riparian setbacks include the entire active floodplain, regardless of the current extent of riparian vegetation on that surface, and that an additional 30 m (98 ft) buffer be included within the setback. Conversion of the active floodplain to developed or agricultural land uses would substantially affect the hydrologic and geomorphic processes that sustain salmonid habitat functions. Land adjacent to the active floodplain also may affect shade, inputs of woody debris, and water quality; consequently, the 30 m (98 ft) buffer would reduce the effects of adjacent land uses.

It is important to recognize that riparian setbacks are not sufficient to ensure conservation of salmonid habitat functions. Many effects on salmonid habitat functions result from human alterations that are unrelated to setback width, but that are rather associated with flow alterations, water quality, vegetation management, and land uses within the watershed. Therefore, conservation of salmonid habitat functions requires the implementation of a coordinated set of measures involving land use, flow management, and vegetation management in these watersheds and within these defined setbacks.

Chapter 5
Plant Habitat Functions

Introduction

More than 15 native tree and shrub species occur in the riparian forests, woodlands, and scrublands of the Sacramento Valley and adjacent foothills (Conard et al. 1980). These species are all deciduous, and all require high or very high levels of water availability. They differ in their dispersal mechanisms, seed size, shade tolerance, size, growth rates, and longevity (Table 5-1). These attributes, in concert with site conditions and flow and disturbance regimes, determine the species composition and structure of riparian vegetation.

In the Sacramento Valley, early successional vegetation typically is dominated by Fremont's cottonwood (*Populus fremonti*) and willow species (*Salix* spp.). Both taxa produce large numbers of widely dispersed seeds and are rapidly growing, shade intolerant, and relatively short-lived (Sudworth 1908; Strahan 1984; Burns and Honkala 1990). Shrubby thickets of these species can reach heights of 3–12 m (10–40 ft) over a period of 10–20 years. Other species, such as Oregon ash (*Fraxinus latifolia*) and valley oak (*Quercus lobata*), establish either concurrently with or subsequent to the willows and cottonwood and grow more slowly, but they are more tolerant of shade and are longer lived (Burns and Honkala 1990; Tu 2000). In the absence of frequent disturbance, individuals of these species enter the canopy, particularly after 50 years since stand initiation, as mortality of willows and cottonwoods create openings in the forest canopy. Conversely, frequent disturbance prevents the transition to mature mixed riparian or valley oak forests. Currently, in western Placer County, oak species are abundant in the riparian vegetation, white alder (*Alnus rhombifolia*) is widespread, and cottonwoods and willows are less abundant than along many other Central Valley rivers and streams (Appendix A; Placer County 2002).

Human alterations of riparian areas change site conditions, including flow and disturbance regimes, and consequently affect the dispersal, establishment, growth, reproduction, and mortality of riparian species. These changes alter the species composition and structure of riparian vegetation, thereby modifying habitat for aquatic fish and terrestrial wildlife habitat, as well as biogeochemical functions.

Effects of Human Alterations on Life Cycle of Riparian Species

Effects on Dispersal

Air, water and animals disperse riparian plant species. However, flow regime strongly affects the dispersal of all plant species. Surfaces that remain submerged throughout the period of seed release are largely inaccessible to most dispersing seed, and surfaces that remain above water during this period are inaccessible to water-dispersed seed. Seeds are commonly dispersed through the air or by floating on water; large numbers of seeds wash onto shorelines and bars as water levels recede. The river stage during the dispersal period must be at a level high enough to distribute seeds to a surface where scouring by subsequent flows does not occur, and low enough to prevent desiccation of seedlings once the river stage recedes.

Accordingly, hydrologic or geomorphic alterations affect the dispersal of riparian plant species. Levees and berms isolate surfaces from stream flows and preclude the deposition of water-dispersed seed. Flow alterations modify the river's stage, raising or lowering the elevation at which seeds are deposited. Similarly, incision of the stream channel lowers the river's stage, and thus lowers the elevation at which seeds are deposited. Such incision is widespread in western Placer County (Appendix A; Placer County 2002; ECORP 2003; EDAW 2004; Jones & Stokes 2004 c).

Similarly, conversion of active floodplain to agricultural or developed land uses can isolate seed sources and potentially create barriers to flows or animal movements and thus to seed dispersal. However, the extent of these effects is not well known.

Effects on Establishment

Establishment of riparian plants requires suitable conditions for germination and subsequent growth. Hydrology and hydraulics, soil properties, competing vegetation, disease-causing organisms, herbivorous animals, and vegetation management by humans all affect the transition from seed to established plant.

For successful recruitment, cottonwood and willows are particularly dependent on specific hydrologic events before, during, and immediately following their seed release periods. These shade-intolerant species have very small and short-lived seeds (Table 5-1); accordingly, they require establishment sites that are largely free of competition from existing vegetation. The erosion and deposition of sediment along stream channels and on floodplains creates such surfaces. A moist substrate must be maintained for approximately a week following seed dispersal to allow seeds to germinate (Scott et al. 1999, 2000). Following germination, the river stage must decline gradually to enable seedling

Table 5-1. Selected Attributes of Sacramento Valley and Foothill Riparian Tree Species

Species	Seed Size[a]	Seedling Shade Tolerance[b]	Height[c]	Longevity[d] (years)
Box-elder *Acer negundo*	0.1 g (0.001 oz.)	Tolerant	15-25 m (49-82 ft)	50-100
White Alder *Alnus rhombifolia*	0.001 g (0.0001 oz.)	Intolerant	15-25 m (49-82 ft)	50-100
Oregon ash *Fraxinus latifolia*	0.1 g (0.001 oz.)	Tolerant	10-25 m (33-82 ft)	150-250
Walnut *Juglans hindsii*	10.0 g (0.1oz.)	Intermediate	10-20 m (33-66 ft)	50-150
Sycamore *Platanus racemosa*	0.01 g (0.0001 oz.)	Intolerant	10-30 m (33-98 ft)	150-200
Fremont's cottonwood *Populus fremontii*	0.001 g (0.0001 oz.)	Intolerant	15-30 m (49-98 ft)	50-100
Valley oak *Quercus lobata*	1.0 g (0.1 oz.)	Intermediate	10-35 m (33-115 ft)	300-400
Interior Live-oak *Quercus wislizenii*	1.0 g (0.1 oz.)	Intermediate	5-20 m (16-66 ft)	100-200
Goodding's black willow *Salix gooddingii*	0.0001 g (0.00001 oz.)	Intolerant	10-30 m (33-98 ft)	50-100
Narrow-leaved willow *Salix exigua*	0.0001 g (0.00001 oz.)	Intolerant	5 m (16 ft)	20-30
Red willow *Salix laevigata*	0.0001 g (0.00001 oz.)	Intolerant	10-15 m (33-49 ft)	40-60
Arroyo willow *Salix lasiolepis*	0.0001 g (0.00001 oz.)	Intolerant	5-10 m (16-33 ft)	30-50
Shining willow *Salix lucida*	0.0001 g (0.00001 oz.)	Intolerant	5-10 m (16-33 ft)	30-50

[a] = Based on information in Schopmeyer 1974, and rounded to nearest order of magnitude
[b] = Based on information in Sudworth 1908, Burns and Honkala 1990
[c] = Based on information in Hickman 1993, Stuart and Sawyer 2001
[d] = Based on information in Burns and Honkala 1990, Sudworth 1908 and J. Hunter unpublished data
g = grams
oz = ounces
m = meters
ft = feet

establishment. If the river stage declines too quickly, seedlings are prone to mortality by desiccation. To supply seedlings with adequate water as their roots elongate toward the water table, the decline in river stage should not exceed 2.5-3.8 cm (1–1.5 inches) per day (Mahoney and Rood 1998; Shafroth et al. 1998; Scott et al. 1999, 2000).

After germination, seedlings grow on surfaces ranging from immediately below peak-flow to immediately above low-flow elevations. Most seedlings do not survive their first year on these surfaces. Because high levels of soil moisture within several feet of the surface are required for these seedlings to survive through the first summer, seedlings may desiccate on higher elevation surfaces. Moreover, prolonged inundation during the growing season can kill seedlings (Sprenger et al. 2001). Under unaltered conditions, high summer flows typically do not occur; however, where streams are downstream of dams or are used to convey irrigation waters, high summer flows may frequently occur. Finally, flows during the following winter and spring may inundate all surfaces supporting seedlings; seedlings may be scoured from those surfaces inundated with sufficient depth and velocity of water to mobilize the surface (Friedman and Auble 1999). Such scouring is most likely on lower-elevation surfaces.

Historically, flows suitable for cottonwood and willow establishment did not occur in most years. Historical records and tree-aging studies have shown that in numerous riverine environments in the western United States, the combination of factors leading to a large-scale establishment event typically occurs once every 5–10 years (Stromberg et al. 1991; Scott et al. 1997; Mahoney and Rood 1998). Scott et al. (1997) determined that establishment of cottonwoods on the upper Missouri River in an area with little channel movement was most likely on surfaces inundated by floods with a recurrence interval of more than 9 years. Hughes (1994) concluded that long-term cottonwood establishment was associated with even longer flood return intervals (30–50 years) along some non-meandering rivers.

Because other species of riparian trees and shrubs are characterized by larger seed sizes and greater shade tolerance than willows and cottonwoods (Table 5-1), the establishment of such species is less dependent on stream flows. All riparian plants are affected by water availability and competition from existing vegetation, and are consequently affected to some degree by hydrology and the creation of new surfaces by the erosion and deposition of sediment. Some species, such as Oregon ash and valley oak, are able to establish in the shade of other plants; others, such as elderberry and valley oak, can survive drier conditions than can cottonwoods and willows. Thus, in the absence of suitable conditions for willow and cottonwood establishment, other riparian species establish, but the resulting stands differ from cottonwood and willow–dominated stands in species composition, structure, and wildlife habitat value.

Vegetation management activities also affect the establishment of all riparian species. Such activities entail removal of vegetation by means of grazing, herbicide application, and mechanical operations for rangeland and agricultural management; firewood cutting; and levee, floodway, road, and right-of-way maintenance. (Silviculture is not a widespread practice in the Sacramento Valley and foothill riparian areas.) While vegetation removal kills seedlings, it also removes established plants, creating greater opportunities for establishment in subsequent years.

Vegetation management activities occur in western Placer County and may be detrimentally affecting the regeneration of riparian vegetation. Despite stands having a sparse layer of trees and a narrow width, small saplings (i.e., < 2 m [6.6 ft]), particularly those of cottonwoods or willows, often are rare or absent (Appendix A; Placer County 2002). However, hydrologic alterations also may account for these conditions.

Effects on Growth and Reproduction

Growth and reproduction of riparian plants are affected by changes in resource availability and interactions with other species. The effects of human alterations on reproduction have not been documented, except to the extent that reproduction is dependent on growth, and effects on growth have been documented. Human alterations affect the growth of riparian species through surface water diversions and groundwater removals, nutrient inputs, the introduction of nonnative species, and inundation of riparian habitats by dams and reservoirs.

Beyond providing suitable conditions for establishment, flows must be sufficient to maintain existing riparian vegetation year-round. Cottonwoods and willows, in particular, are very susceptible to drought-induced stress. In California, the lack of summer moisture limits these and other riparian tree species to areas with readily available shallow groundwater. Accordingly, groundwater and flows following seedling establishment must be sufficient to maintain the elevation of the riparian groundwater zone or capillary fringe within 10–20 feet of the surface (Jones & Stokes 2000a). Diversions of surface water and groundwater removals that cause groundwater levels to fall could reduce growth and contribute to mortality (Stromberg and Patten 1992). Human alterations increase nutrient inputs to riparian areas thorough atmospheric deposition of nitrogen; additionally, irrigation and stormwater runoff conveys fertilizers from agricultural and developed lands into riparian areas and stream channels. Though the addition of nutrients tends to increase plant growth and biomass, it also affects the cycling of other elements and does not benefit all species equally (Vitousek et al. 1997). Typically, a few species are able to acquire most of the added nutrients, and consequently to outcompete species they would otherwise have been unable to displace. In grasslands, shrublands, and wetlands, nutrient additions have been found to reduce plant species diversity (Vitousek et al. 1997; Keddy 2000). Effects on woody riparian vegetation are undocumented, but are likely to be similar to those reported for other vegetation types.

A number of nonnative species have been introduced and become abundant in the riparian areas of the Sacramento Valley and adjacent foothills (Hunter et al. 2003). These nonnative species create new competitive interactions, and they alter growth by changing resource availability for native species. For example, several introduced species, including black locust (*Robinia pseudoacacia*) and red sesbania (*Sesbania punicea*), fix nitrogen from the atmosphere into biologically available forms via symbioses with soil microorganisms (Hunter 2000; Hunter and Platenkamp 2003). These introduced species may increase nutrient availability for other species. In contrast, tamarisk (*Tamarix* spp.) may reduce water availability for other species (Sala et al. 1996). Several invasive nonnatives, including red sesbania, Himalayan blackberry (*Rubus discolor*), giant reed (*Arundo donax*), and perennial pepperweed (*Lepidium latifolium*), form dense, monotypic stands that preclude the establishment of native species (Bossard et al. 2000).

In western Placer County, many of these invasives are widespread and abundant. For example, Himalayan blackberry is the most abundant species in the shrub layer along western Placer County's streams, and red sesbania grows widely along Dry Creek (Appendix A; ECORP 2003). This non-native vegetation has displaced native species and altered several riparian functions (e.g., conveyance of floodwaters, nitrogen cycling and wildlife habitat).

Effects on Mortality

The mortality resulting from disturbance is integral to the dynamics of riparian vegetation; it affects the proportions of different successional stages and vegetation types within riparian corridors (Stromberg et al. 1991; Malanson 1993; Johnson 1994; Freidman and Auble 1999; Taylor et al. 1999). Along Sacramento Valley and foothill rivers and streams, trees are killed by a number of mechanisms including scour, undercutting by channel migration, uprooting and inundation by flood flows, drought, fire, windthrow, and the removal of vegetation for agricultural or flood control purposes. These disturbances clear spaces for the establishment of early successional vegetation, such as willow thickets and forests dominated by young Fremont's cottonwoods. They also can remove forest vegetation before growth and succession has resulted in the complex canopy structures of mature forests and later successional stages, such as mixed riparian forests and stands of valley oaks. Thus, disturbance regimes determine the proportions of early and late successional vegetation within riparian landscapes.

To maintain both early successional vegetation and mature forests within a riparian landscape, the rate of disturbance must be sufficient to create space for the establishment of new patches of riparian forest, yet not so frequent that it prevents any forest from reaching maturity. Of course, disturbances are not randomly distributed spatially or by type (Conard et al. 1980; Hunter and Parker 1993; Malanson 1993; Freidman and Auble 1999). Disturbance by scour, channel migration, flood flows, and inundation are more frequent and intense at lower elevations (i.e., nearer the stream channel) than at higher elevations (Conard et al. 1980; Malanson 1993; Mitsch and Gosselink 1993; Freidman and Auble 1999; Keddy 2000). In contrast, along Central Valley riparian systems, disturbance by drought and fire is more frequent and intense at higher elevations further from the channel. Thus, across a single cross-section of a riparian corridor, clear gradients exist in disturbance frequency and magnitude. These disturbance gradients, together with interspecific differences in physiological tolerances and establishment requirements, lead to the well-documented zonation of riparian vegetation (Conard et al. 1980; Warner and Hendrix 1985; Mitsch and Gosselink 1993). Accordingly, the persistence of substantial areas of both early successional and mature vegetation within riparian areas is not dependent upon a specific overall average rate of disturbance; rather, it requires only zones of higher and lower rates of disturbance. The combination of flood flows, an actively meandering river channel, and a range of elevations provide such zonation.

Human alterations not only change mortality rates by directly removing vegetation but also by altering hydrology and geomorphic processes. Dams, levees, and surface water diversions isolate riparian areas from the stream channel and floodflows, and thus from associated disturbances. Similarly, bank protection and channelization reduce mortality that can result from channel migration. In addition, groundwater removals can reduce water availability and exacerbate drought-induced mortality of riparian plants.

In western Placer County, substantial areas of riparian vegetation have been converted to developed and agricultural land-cover (Jones & Stokes 2004a, 2004b). For example, along the major streams of western Placer County, approximately a quarter of the land < 20 m (66 ft) from the centerline of a stream, is in developed or agricultural land-cover (Jones & Stokes 2004a, 2004b). The remaining riparian vegetation frequently consists of a narrow band (< 20 m [66 ft]) with a discontinuous layer of trees (Appendix A).

Relationships Between Effects and Setback Width

Human alterations primarily affect riparian plant habitats by vegetation management (e.g., grazing, removal of vegetation to increase conveyance of floodwaters) or by altering hydrology and geomorphic processes. Vegetation management is not necessarily related to setback width, but alterations of hydrologic and geomorphic processes are related to setback width. Infrastructure and other developed land uses within the active floodplain, as well as associated levees, berms, and bank protection, affect hydrology and geomorphic processes; such uses consequently alter the structure and species composition of riparian vegetation. Thus, riparian setbacks narrower than the active floodplain facilitate much more extensive alteration of riparian vegetation than setbacks that extend beyond the active floodplain.

Recommended Setback Width to Conserve Plant Habitat Functions

For the purpose of long-term conservation of plant habitat functions, the project team recommends that riparian setbacks include the entire active floodplain, regardless of the current extent of riparian vegetation on that surface. The distribution of riparian vegetation is not static within the active floodplain, and the diversity of vegetative structure and species composition is strongly related to the hydrologic and geomorphic processes within the active floodplain. Therefore, conversion of any portion of the active floodplain to developed or agricultural land-cover types would not only affect hydrologic and geomorphic functions but would affect plant habitat functions as well.

It is important to note that many human effects on riparian plant habitat functions are not necessarily reduced by establishing setbacks. These effects include the consequences of hydrologic and geomorphic alterations and of vegetation management. Additional measures are necessary to address these effects.

Chapter 6
Terrestrial Animal Habitat Functions

Introduction

The contribution of riparian habitats to biodiversity greatly exceeds the proportional extent of landscape areas they occupy. Scientific documentation of the importance of these habitats for plants and animals has been published in studies conducted across the continent (Sands 1977, Warner and Hendrix 1984, Naiman et al. 1993, 2000; Crow et al. 2000; Brinson et al. 2002).

In western Placer County, Valley Foothill Riparian Woodlands (riparian woodlands) (Mayer and Laudenslayer 1988) and their associated upland habitats provide food, water; cover and migration and dispersal corridors for a higher diversity of wildlife species than any other habitat. Riparian woodlands may support up to 193 vertebrate species, including 133 breeding species and 60 visitors, in western Placer County (Jones & Stokes 2004a). Some animals reside primarily in riparian woodlands year-round, while others occupy these habitats as part of their breeding home range or territories. Many species visit riparian woodlands seasonally or for short periods (e.g., migrating birds).

A number of special-status animals are known to be associated with riparian woodlands in western Placer County: valley elderberry longhorn beetle, foothill yellow-legged frog, western pond turtle, giant garter snake, double-crested cormorant, great egret (rookery), great blue heron (rookery), black-crowned night-heron (rookery), bald eagle, Swainson's hawk, osprey, white-tailed kite, Cooper's hawk, yellow-billed cuckoo (one historical record), long-eared owl, willow flycatcher, purple martin, yellow warbler, yellow-breasted chat, Modesto song sparrow, river otter, ringtail, and an unknown number of bat species (e.g., Townsend's big-eared bat, long-eared myotis, long-legged myotis, and Yuma myotis).

Riparian-associated species vary considerably in their area requirements; many special-status and declining species have large home ranges, and thus require wide riparian areas to maintain viable populations. The habitat and area requirements of riparian-associated birds, mammals, reptiles, and amphibians in western Placer County are summarized in Table 6-1. This list includes only species that depend on riparian woodlands for successful reproduction and survival. Plant and animal population size is often the best predictor of future extinctions or local extirpations; accordingly, habitat patches should be large enough to maintain viable populations of the most area-sensitive species, including special-status and economically important species (Environmental Law Institute 2003).

The primary goal of this chapter is to examine the possible relationships between terrestrial vertebrate diversity (i.e., species' occurrence and abundance) and the extent, width, and condition of riparian woodlands in western Placer County and nearby foothill counties. For each vertebrate group discussed below, the project team evaluated riparian and upland habitat requirements, patch size requirements (area and width), and effects of human activities on those vertebrate groups. The chapter concludes with a summary of the relationships between the width of riparian setbacks and the effects on wildlife habitat due to human alterations, and setback recommendations for conservation of wildlife habitat functions.

Birds

Habitat Relationships

Riparian habitats have been identified as the most important habitat for landbirds in California (Manley and Davidson 1993, Riparian Habitat Joint Venture 2004). Birds of numerous species are abundant in riparian woodlands of western Placer County. Up to 70 species breed in these habitats; an additional 55 species use them for shelter, foraging, or as migratory stopover areas (Jones & Stokes 2004a). Several riparian-associated birds may be covered under the HCP/NCCP for the Phase I Planning Area: Swainson's hawk, yellow-billed cuckoo (one historical record), yellow warbler, yellow-breasted chat, and Modesto song sparrow. Two potentially covered species (bald eagle and bank swallow) may use these habitats for foraging, shelter, or cover but do not breed there (Jones & Stokes 2004a).

Many species of riparian-associated birds are known to breed in western Placer County. These include Cooper's hawk, red-shouldered hawk, Swainson's hawk, black-chinned hummingbird, downy woodpecker, western wood-pewee, Pacific-slope flycatcher, warbling vireo, tree swallow, house wren, yellow warbler (no recent breeding records), yellow-breasted chat, common yellowthroat, Modesto song sparrow, black-headed grosbeak, blue grosbeak, and American goldfinch (Table 6-1).

Riparian Habitat Requirements

Riparian-associated bird species occupy a wide variety of ecological niches; accordingly, they require a complex vegetative structure for breeding, foraging, and shelter/cover (Riparian Habitat Joint Venture 2004). Riparian woodlands provide many niches for breeding birds because they typically support diverse plant communities, are varied in their vertical and horizontal structures, and

			Riparian		Upland	
Species	Home Range Size	Territory Size	Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Pacific treefrog* *Hyla regilla*	Most move < 10 m; capable of moving up to 400 m (Schaub and Larsen 1978)	Circles with radii of 50 cm (Whitney 1980)	Breeding, cover, foraging	Breeds in water; takes cover under logs and vegetation. Uses all riparian stages and temporary water sources (Zeiner et al. 1988)	Cover, foraging	Requires upland sites for cover during nonbreeding season, takes cover in moist niches under logs and vegetation (Zeiner et al. 1988)
Common garter snake* *Thammophis sirtalis*	Probable overlap between pairs during the spring-fall activity period (Zeiner et al. 1988)	Not thought to be territorial; they often remain aggregated from fall until spring (Zeiner et al. 1988)	Cover, foraging, breeding	Permanent and semi-permanent water bodies. Seeks cover in holes and small mammal burrows, often basks on flat rocks and rotting logs near cover (Zeiner et al. 1988)	Cover, foraging, but only in cold northern climates	May migrate to inland localities during winter in cold northern climates (Zeiner et al. 1988)
Western terrestrial garter snake* *Thamnophis elegans*	Probable overlap between pairs during the summer activity period (Zeiner et al. 1988)	Not thought to be territorial (Zeiner et al. 1988)	Cover, foraging, breeding	Permanent and semi-permanent water bodies. Seeks cover in holes and small mammal burrows, often basks on flat rocks and rotting logs near cover (Zeiner et al. 1988)	Cover, foraging	In mild climates, mammal burrows and surface objects (rocks and rotting logs) serve as winter refuges (Zeiner et al. 1988)
Giant garter snake* *Thamnophis couchi gigas*	Probable overlap between pairs during summer activity period; may migrate between wetland habitats and upland sites that provide winter hibernacula (Zeiner et al. 1988)	Not thought to be territorial (Zeiner et al. 1988)	Cover, foraging, breeding	Highly aquatic; seeks cover in holes and small mammal burrows, crevices, and surface objects. Often basks in streamside vegetation. Rocks and rotting logs serve as winter refuges	Cover, foraging	In mild climates, mammal burrows and surface objects (rocks and rotting logs) serve as winter refuges (Zeiner et al. 1988)
Cooper's hawk *Accipiter cooperii*	*Michigan* – four home ranges averaged 311 ha, range 96–401 ha; 17 others averaged 207 ha, range 18–531 ha *Wyoming* – One home range of 205 ha (Craighead and Craighead 1956).	Males defend ~100 m around potential nest sites prior to pair formation (Brown and Amadon 1968). *Oregon* – nests were 3.2–4.2 km apart (Jackman and Scott 1975). Elsewhere, nests were 1.6–2.4 km apart (Meng 1951, Brown and Amadon 1968). *California* – In oak stands, mean distance between nests was 2.6 km (Zeiner et al. 1990a)	Breeding, foraging, perching	Needs dense stands of live oak, riparian deciduous, coniferous, or other forest habitats near water; nests in crotches 3–23 m high (Zeiner et al. 1990a)	Breeding, foraging, perching	Hunts in patchy wooded areas and edges; needs snags or dense tree stands for perching and waiting for prey (Beebe 1974). Dense stands with moderate crown-depths used for nesting (Zeiner et al. 1990a)

			Riparian		Upland	
Species	Home Range Size	Territory Size	Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Red-shouldered hawk* *Buteo lineatus*	*Michigan* – averaged 63 ha, range 19–384 ha (Craighead and Craighead 1956)	Same as home range	Breeding, perching, foraging	Extensive stands of forest with tall trees and variable amounts of understory required for breeding (Crocoll 1994)	Cover, foraging	Does not require upland sites, but will use them for foraging and roosting; mostly forages in oak woodlands and adjacent annual grasslands (Zeiner et al. 1990a)
Swainson's hawk+ *Buteo swainsoni*	*Wyoming* – five pairs averaged 2.5 km^2 (Craighead and Craighead 1956) *California* – 12 pairs, 2,760–2,553 ha (Estep 1989); 5 pairs ranged 4,038–2,663 ha (Babcock 1995) *Washington* – eight pairs, 621–214 ha (Fitzner 1978); five pairs, 886–243 ha (Bechard 1982) *Colorado* – eight pairs, 2,429–1,050 ha (Andersen 1995) Nest sites in riparian forest close to alfalfa or recently harvested row crops corresponded to smaller home ranges (Estep 1989)	No specific information on territory size (England et al. 1997); three territories were found within a 1.1-km length of riparian forest in the Central Valley (Bloom 1980)	Breeding and perching	Requires large trees to support nests, but will nest in open habitats with scattered trees and small groves near water (Bloom 1980); nests 1.3–30 m above ground (Zeiner et al. 1990a)	Breeding, foraging, perching	Not an obligate riparian species; needs proximity to good foraging habitat such as grassland, pasture, or grainfields; primarily needs large trees for nesting (Woodbridge 1998; Zeiner et al. 1990a); may nest in open grassland or cropland habitats with scattered trees (England et al. 1997)
Yellow-billed cuckoo+ *Coccyzus americanus*	Large home ranges averaging 17 ha (Laymon and Halterman 1987)	10 ha is an appropriate minimum patch size (Halterman pers. comm.)	Nesting, foraging, perching	Optimal stands defined as more than 80 ha in extent and more than 600 m wide, marginal stands as 20–40 ha and 100–200 m wide, and unsuitable stands as less than 15 ha and less than 100 m wide (Laymon and Halterman 1989)	Foraging	May forage in uplands adjacent to riparian woodlands, especially early successional stands of cottonwoods and willows (Laymon and Halterman 1989). 10 ha is an appropriate minimum patch size for this species (Halterman pers. comm.)

Species	Home Range Size	Territory Size	Riparian Habitat Use	Riparian Habitat Requirements	Upland Habitat Use	Upland Habitat Requirements
Black-chinned hummingbird+ *Archilochus alexandri*	No data	*S. California* – male breeding territory averaged 0.1 ha (Stiles 1973); 41–130 nests per 40 ha (Pitelka 1951) *Arizona* – eight nests per 40 ha in oak woodland; 21 per 40 ha in oak juniper woodland (Balda 1970)	Nesting, foraging, perching	Sparse to open riparian woodland preferred for breeding; uses trees and shrubs for cover; places open cup nest in understory (0.9–9.1 m above ground) near water source (Grinnell and Miller 1944; Zeiner et al. 1990a)	Occasional breeding, mostly foraging	Woodland and scrub habitats adjacent to riparian areas used for feeding during breeding season. Occasionally nests in orchards (Zeiner et al. 1990a)
Downy woodpecker* *Picoides pubescens*	Territory and home range are the same (Zeiner et al. 1990a)	*Ontario* – two breeding territories of 2.0 and 3.2 ha (Lawrence 1967)	Breeding, foraging, cover	Associated with riparian deciduous softwoods; uses tree and shrub foliage for cover; requires abundant snags and tree/shrub, tree/herbaceous, and shrub/herbaceous ecotones (Zeiner et al. 1990a). Excavates nest cavity in snag (preferably aspen) or dead branch 1.3–15 m high (Bent 1939; Lawrence 1967)	Foraging, cover	Frequents hardwoods, conifer habitats, and orchards adjacent to riparian areas (Zeiner et al. 1990a)
Western wood-pewee+ *Contopus sordidulus*	No information found, but probably equal to territory. Density estimates range from 1–10 pairs per 40 ha in Colorado aspen-conifer habitat (Beaver and Baldwin 1975) to 18–33 pairs per 40 ha in Sacramento Valley riparian habitats (Gaines 1974)	*Colorado* – territory averaged 1.2–1.6 ha over 3 yrs (Eckhardt 1976). Territory size probably varies widely depending on habitat and foraging conditions (Zeiner et al. 1990a)	Breeding, perching, foraging	Uses trees of almost any size, especially with dead lower branches, for nesting, singing, and foraging perches. Places open cup nest 4–25 m above ground. Nests in woodlands edging riparian areas and in valley foothill riparian habitats (Zeiner et al. 1990a)	Breeding, roosting, foraging	Nests in open woodlands with sparse to moderate canopy, most commonly in ponderosa pine, montane hardwood-conifer, mixed conifer, Jeffrey pine, lodgepole pine, eastside pine, red fir, and aspen (Grinnell and Miller 1944; Garrett and Dunn 1981; Zeiner et al. 1990a)

			Riparian		Upland	
Species	Home Range Size	Territory Size	Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Willow flycatcher+ *Empidonax traillii*	In breeding season, probably equal to territory. *Washington* – 9.2 pairs per 40 ha in scrub habitat (King 1955) *Michigan* – 60.7 individuals per 40 ha in scrub habitat (Berger 1957)	*California* - six paired males ranged 0.09–0.38 ha and averaged 0.18 ha in Fresno County (KRCD 1985); 22 territories ranged 0.06–0.89 ha and averaged 0.34 ha in Sierra County (Sanders and Flett 1989); monogamous males averaged 0.6 ha (SD = 0.35, n = 24, range 0.1–1.3) and polygynous males averaged 1.1 ha (SD = 0.68, n = 24, range 0.2–2.8) at the South Fork Kern River (Whitfield and Strong 1995; Whitfield and Enos 1996; Whitfield et al. 1997). *Arizona* – range 0.06–1.5 ha (Sogge et al. 1997). *Michigan* – avg. size was 0.7 ha (Walkinshaw 1966)	Nesting, foraging, perching	Broad river valleys or moist mountain meadows where lush thickets of dense willows, alders, and cottonwoods edge on wet meadows, ponds, or backwaters (Zeiner et al. 1990a; Serena 1982; Harris et al. 1988; Whitfield et al. 1997; Sanders and Flett 1989). In mountain meadows prefers willow thickets interspersed with open space; in lowland riverine habitats prefers contiguous willow thickets (Harris 1991). Does not occur in areas of dense tree cover (King 1955; Walkinshaw 1966)	Migration	May migrate into higher elevations after breeding and during fall migration (Grinnell and Miller 1944). No specific data un upland habitat use
Pacific-slope flycatcher+ *Empidonax difficilis*	*Colorado* – 5–28 individuals/40 ha in conifer forest (Beaver and Baldwin 1975) *California* – 11 males/40 ha in broadleaf evergreen forest in Alameda County (Cogswell 1973), 35 males/40 ha in buckeye/California bay mixed forest in Marin County (Stewart 1973)	No data	Breeding, foraging, perching	Breeds in shady alder and willow thickets and similar riparian growth in oak woodlands, redwood, and ponderosa pine forests (Zeiner et al. 1990a)	Foraging, perching, migration	Frequents shaded woodlands and forests with dense canopy adjacent to riparian habitat during breeding season. Occurs in more open habitats in migration (Zeiner et al. 1990a)

			Riparian		Upland	
Species	Home Range Size	Territory Size	Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Warbling vireo+ *Vireo gilvus*	*Idaho* – one pair had a 37-m radius around the nest (Rust 1920); five pairs/40 ha in a cut-over Douglas-fir forest (Johnston 1949) *Arizona* – 42 pairs/40 ha in fir-pine-aspen forest (Haldeman et al. 1973) *California* – 40 pairs/40 ha in an oak/bay mixed forest (Stewart 1973); 21 pairs/40 ha in a lodgepole-aspen forest (Winkler and Dana 1977); eight pairs/40 ha in a broadleaf evergreen forest (Cogswell 1973)	*California* – nine pairs in coastal riparian forest averaged 1.45 ha; 19 territories in eastern California averaged 1.2 ha (Gardali and Ballard 2000) *Arizona* – 2 pairs were both 1.2 ha (Barlow 1977). *Illinois* – One pair was ~1.2 ha (Gardali 2003). *Ontario* – Three pairs ~1.2-1.5 ha (Gardali 2003). *Alberta* – Two pairs were both 1.5 ha (Gardali 2003)	Breeding, foraging, perching	Nests in mature mixed deciduous woodlands along riparian corridors (Gardali 1998). Likes edges and openings, large trees, and semi-open canopy (James 1971; MacKenzie et al. 1982; Marzluff and Lyon 1983; Verner and Boss 1980) According to Grinnell and Miller (1944), may be more attracted to riparian trees than to moisture	Occasional breeding, perching, and migration	Commonly uses deciduous trees, shrubs and conifers for cover. Occasionally breeds in conifer habitats and forest interiors near edges and openings (Zeiner et al. 1990a; Gardali 1998). Also occurs in desert riparian, orchards, vineyards, and urban habitats during migration (Zeiner et al. 1990a; Gardali 1998)
Tree swallow+ *Tachycineta bicolor*	Kuerzi (1941) stated home range is “large”	*California* – 4–18 pairs/40 ha in riparian habitat (N = 3) and 2–10 pairs/40 ha in mixed conifer forest (N = 4) in the Sierra Nevada (Raphael and White 1978)	Breeding, foraging, cover	Requires trees and snags with cavities in forest and riparian woodland for nesting and cover (Zeiner et al. 1990a)	Breeding, foraging, perching, migration	Will nest in lodgepole pine belts. Common to occasional transient throughout the state in virtually all non-desert habitats (Zeiner et al. 1990a)
House wren* *Troglodytes aedon*	No data	*Oregon* – 14 breeding territories averaged 0.9 ha, range 0.5–1.8 ha (Kroodsma 1973) *Ohio* – 178 breeding territories averaged 0.4 ha, range 0.03–1.5 ha (Kendeigh 1941b)	Breeding, foraging, cover	Brushy understory beneath oaks and other riparian deciduous trees. Requires cavities in trees and snags with thickets nearby for foraging (Zeiner et al. 1990a)	Dispersal	Moves upslope after breeding in the Cascades and Sierra Nevada (Zeiner et al. 1990a)

			Riparian		Upland	
Species	Home Range Size	Territory Size	Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Yellow warbler+ *Dendroica petechia*	*New York* – less than 0.2 ha (Ficken and Ficken 1966) *Iowa* – 0.16 ha (Kendeigh 1941a)	*California* – 0.40–.74/ha (mean 1.64 SE + 0.12) in early successional habitats of eastern Sierra Nevada (PRBO unpublished data) *Iowa* – 0.16/ha in prairie community *Minnesota* – range 0.03–1.62 ha (Beer et al. 1956) *Michigan* – polygynous male territories (0.78 ha) significantly larger than those of monogamous males (0.21 ± 0.05 ha) (DellaSala 1986) Territory size variable depending on availability of foraging area (Kendeigh 1941)	Breeding, foraging, perching	Nests in early successional riparian habitat or remnant or regenerating canopy with good shrub cover. Prefers deciduous trees such as willows, alders, sycamore, maples, and cottonwoods; in the eastern Sierra breeds locally in wild rose and more xeric plant species and habitats (Heath 1998)	Breeding, foraging, perching	Breeds in montane shrubs in open conifer forests (Gaines 1977). In migration, visits woodland, forest, and shrub habitats (Zeiner et al. 1990a). Kendeigh observed individuals regularly moving up to 488 m to a willow-marsh edge to feed. (Zeiner et al. 1990a). *D.p. brewsteri* was found to breed in locations away from water in the Modoc Bioregion (Grinnell et al. 1930).
Common yellowthroat *, + *Geothlypis trichas*	*Michigan* – 1.4 ha for polygynous male; 10 pairs ranged 0.3–0.7 ha in marsh and riparian habitats (Stewart 1953) *New York* – seven pairs spaced uniformly over 2.0–2.4 ha in a brush field (Kendeigh 1945)	*California* – 1.04 territories/ha in Marin County (Evens et al. 1997); spacing of 0.2–2.0 ha reported by Foster (1977) in the SF Bay *Michigan* – 0.3–0.7 ha (Stewart 1953) *New York* – spacing of 2.0–2.4 ha	Breeding, foraging, perching	Needs tall, emergent herbaceous wetlands and low, dense vegetation near water (Timossi 1990; Zeiner et al. 1990)	Occasional breeding, migration	Occasionally breeds in dense shrubs and annual/perennial grasslands (Garrett and Dunn 1981; Zeiner et al. 1990). Brushy habitats used in migration (Zeiner et al. 1990a)

			Riparian		Upland	
Species	Home Range Size	Territory Size	Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Yellow-breasted chat + *Icteria virens*	*California* – 10pairs/40 ha reported in the Sacramento Valley (Gaines 1974)	*Indiana* – avg. 1.24 ha (range 1.12–1.58 ha). Males that arrived early established large territories that shrunk as more males arrived; males expanded their territories if neighboring territories were abandoned (Thompson and Nolan 1973)	Breeding, foraging, perching	Requires dense riparian thickets of willows, vine tangles, and dense brush associated with streams, swampy ground, and borders of small ponds (Small 1994). Uses taller trees as song perches (Dunn and Garrett 1997). Nest substrate in California consists of blackberry, wild rose, and pipevine (Ricketts and Kus 2000; Burnett and DeStaebler 2002)	Dispersal	May wander upslope post-breeding (Gaines 1977)
Song sparrow * *Melospiza melodia*	*New York* – 0.6 ha (Butts 1927) *Kansas* – 3.6 ha winter home range; 29 home ranges averaged ~2.8 ha (Fitch 1958) *British Columbia* – averaged 0.05 ha in an island population (Tompa 1962)	*California* Modoc Bioregion: 1.94 territories/ha (n=14) (King and King 2000). Sierra Bioregion: 0.2–1.2 territories per creek km (Heath and Ballard 1999) Bay/Delta Bioregion: 4.4–8.1 territories/ha (Gardali et al. 1998) *British Columbia* – 1.7–5.6 pairs/ha (Rogers et al. 1997)	Breeding, foraging, perching	Breeds in early successional riparian habitat, emergent wetlands, and coastal scrub (Burridge 1995; Roberson and Tenney 1993). Requires water, dense vegetation, light, and exposed ground for foraging (Marshall 1948) Abundance is negatively correlated with tree cover and closed canopy cover ($p<0.05$) (Holmes et al. 1999)	Breeding, foraging, perching	Regularly breeds in coastal scrub habitat, which provides enough water in the form of fog (Humple and Geupel 2004). In winter may be found far from water, in open habitats with thickets of shrubs or tall herbs. Usually avoids densely wooded habitats, except along forest edges (Zeiner et al. 1990a)
Black-headed grosbeak+ *Pheucticus melanocephalus*	*California* – 31–66 singing males/40 ha (Gaines 1974)	*New Mexico* – 0.79 ha (n=28, range=0.43-1.63ha) (Hill 1988; Hill 1995) *Utah* – 2.7 ha (n=12, range=1.9–3.0 ha) (Ritchisson 1983) No information available for California	Breeding, foraging, perching	Requires vegetation density and vertical complexity (Hill 1988); trees and shrubs as low as 1 m to support nests (Zeiner et al. 1990a); favors cottonwood/ willow associations (Grinnell and Miller 1944) with a primary and secondary canopy, variety in shrub height, and patches of herbaceous cover (Gaines 1977)	Occasional nesting, foraging, perching	Sometimes nests in open woodlands, orchards, or edges of dense woodlands (Zeiner et al. 1990a, Lynes 1998)

			Riparian		Upland	
Species	Home Range Size	Territory Size	Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Blue grosbeak+ *Guiraca caerulea*	No data	*South Carolina* – 5.2–6.12 ha (Odum and Kuensler 1955) *Georgia* – 1.2 ha in tung-oil groves (White 1998)	Breeding, foraging, perching	Prefers riparian edges, forest/field edges, or forest/gravel-bar interfaces (Gaines 1974) with herbaceous annuals and young, shrubby willows/cottonwoods (Grinnell and Miller 1944). Prefers upright growing herbs for nest placement, and tall shrubs and trees for singing perches and shade for nest sites (White 1998)	Foraging, dispersal, migration	Forages in openings, grasslands, and croplands adjacent to riparian areas. Not limited to riparian habitats post breeding or in migration (Zeiner et al. 1990a)
American goldfinch* *Carduelis tristis*	*Michigan* – nesters fed up to 274 m from nest (Nickell 1951) and at least 0.8 km from nest (Coutlee 1967); 53–205 pairs/40 ha (Berger 1957) *California* – 10–33 males/40 ha (Gaines 1974)	*Michigan* – males defended 30 m around nest and built nests at least 35 m apart (Coutlee 1967) *Wisconsin* – 9.1–27 m around nest in marshland (Stokes 1950)	Breeding, foraging, perching	Nests in riparian deciduous woodland near feeding areas in brushy or herbaceous habitats (Coutlee 1967). Must be near water and may require trees for roosting (Zeiner et al. 1990a). Uses willow, cottonwood, or other riparian deciduous tree as nesting substrate (Grinnell and Miller 1944)	Breeding, foraging, perching	Will move upslope after breeding (Zeiner et al. 1990a). May nest in oaks, orchards, other upland shrubs, or thistles (Grinnell and Miller 1944)
Ornate shrew* *Sorex ornatus*	Occurrence and abundance of shrews varied significantly between sites and years but the size of the landscape or the study site had no effect on their abundance; peak densities usually occurred during the spring (Laakkonen et al. 2001).	No data found.	Breeding, foraging, cover	Optimum habitats are foothill and montane riparian (Zeiner et al. 1990b). The amount of urban edge had no significant effect on the captures of shrews but increased edge allows invasion of the Argentine ants, which had a highly significant negative impact on shrew abundance (Laakkonen et al. 2001)	Breeding, foraging, cover	Occurs in a variety of woodland, scrub, and grassland habitats and occupies dry, upland sites more commonly than most other shrews (Zeiner et al. 1990b)

Species	Home Range Size	Territory Size	Riparian		Upland	
			Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Yuma myotis *Myotis yumanensis*	Radio telemetry studies showed that direct line distances between capture sites and first day roosts averaged 2,007 m, and 1,130 m for roost sites on consecutive days (Evelyn et al. 2004)	Territoriality has not been reported; probably not territorial at foraging or roosting sites; roosts in large groups numbering from about 200 to thousands of individuals (Zeiner et al. 1990b)	Breeding, foraging, cover	Usually forages over water, and seems to be more closely associated with water than any other North American bat species (Barbour and Davis 1969). Riparian habitats offer optimal habitats for this species since they provide suitable roosting and breeding habitat a nearby source of water for foraging (Zeiner et al. 1990b). Large maternity colonies may be found in buildings, caves, under bridges (Zeiner et al. 1990b), and in large trees (Evelyn et al. 2004). Prefers to roost in large trees (mean diameter 115 cm) that provide suitable cracks, crevices, and cavities; roost sites are usually near water (mean 133 m from water) (Evelyn et al. 2004)	Breeding, foraging, cover	Found in a wide variety of habitats from the coast to mid-elevations, and preferred habitats include open forests and woodlands near sources of water for foraging (Zeiner et al. 1990b).
Beaver* *Castor canadensis*	*Canada*—colonies had home range of 0.8 km radius from lodge, or about 201 ha (Aleksiuk 1968) *California*—colony home range was about 15 ha (Light 1969)	*Canada*--territory boundaries maintained by scent mounds, averaged 0.4 km radius, or about 50 ha (Aleksiuk 1968); colonies closer together formed more scent mounds than did more isolated colonies (Butler and Butler 1979)	Breeding, foraging, cover	In winter forages almost entirely on the bark and cambium of riparian trees including aspen, willow, alder, and cottonwood; forages mostly on streambanks, felling trees and harvesting branches for winter food. Builds lodges out of branches and mud, usually on streamside banks or on islands. Takes cover in lodge or by diving in water; makes dams to form deeper ponds for foraging and taking cover (Zeiner et al. 1990b)	Foraging	Forages us to 200 m from water; cuts a variety of trees but tends to take smaller trees far from water (Jenkins 1980)

Species	Home Range Size	Territory Size	Riparian		Upland	
			Habitat Use	Habitat Requirements	Habitat Use	Habitat Requirements
Ringtail* *Bassariscus astutus*	No information available	*California* – estimated to vary from 44–515 ha (Grinnell et al. 1937) *Texas* – average size estimated at 20–43 ha (Toweill and Teer 1981)	Breeding, foraging, cover	Breeds and takes cover in hollow logs, trees, and cavities in talus and other rocky areas, usually near water (Zeiner et al. 1990b). Primarily carnivorous; prefers rodents and rabbits. Also consumes birds and eggs, reptiles, invertebrates, fruits, nuts, and some carrion (Trapp 1978)	Foraging	Forages primarily in riverine and riparian areas, but may also use nearby uplands if suitable prey is available (Zeiner et al. 1990b)
Raccoon* *Procyon lotor*	*Michigan*—home ranges of males averaged 204 ha and varied from 18 to 814 ha (Stuewer 1943) *North Dakota*—home ranges of males varied from 396 ha to 1,468 ha, and females varied from 532 to 743 ha for females (Fritzell 1977)	Radiotelemetry studies suggest that males may be territorial, but females probably are not; no information on territory size available (Zeiner et al. 1990b)	Breeding, foraging, cover	Found in greatest abundance in low and mid-elevation riparian habitats; takes cover and breeds in tree cavities, snags, and downed logs. Usually forages for both animal and plant material in shallow water (Zeiner et al. 1990b)	Breeding, foraging, cover	Frequents a high diversity of habitats including upland areas such as forested, shrub, and herbaceous areas; may use rocky areas for dens or cover; a source of water is required for foraging and washing (Zeiner et al. 1990b)
River otter* *Lutra canadensis*	Home ranges may extend an average of 24 km along rivers and streams (Haley 1975); travel distance is highly variable and depends on food supplies and habitat quality; may travel 80 to 96 km along streams during a year (Liers 1951)	Males known to establish scent posts using urine, feces, and musk but no information on territory size available ((Zeiner et al. 1990b)	Breeding, foraging, cover	Uncommon residents of riparian habitats and associated streams and rivers; takes cover and nests in burrows and cavities in river banks; also uses hollow logs, stumps, snags, abandoned beaver lodges, and natural cavities in riparian habitats (Zeiner et al. 1990b)	Foraging	Seldom moves away from water but may pursue prey short distances from water courses into upland habitats (Sheldon and Toll 1964)

* Resident (at least partially) in riparian habitats of western Placer County.

+ Neotropical migrant species that breed in riparian habitats of western Placer County or in nearby counties.

provide a source of surface water (MacArthur 1964; James 1971; Rice et al. 1983, 1984; Brinson et al. 2002). Many riparian areas offer a range of successional habitats due to the dynamic nature of their hydrology. Riparian woodlands are also critical to a diversity of migratory birds (e.g., raptors, flycatchers, vireos, warblers, tanagers, sparrows, and grosbeaks) that depend on trees and shrubs near streams for shelter/cover and for the rich food supplies (e.g., insects, seeds, and fruits) associated with these areas (Jones & Stokes 2004a). Moreover, riparian areas can also provide perching, nesting, and foraging habitat, as well as water, for bird species that primarily nest in upland areas (Heath and Ballard 2003).

Because habitat heterogeneity promotes animal diversity, the highest bird abundance and species richness are usually found in riparian woodlands with a variety of different successional stages (i.e., young and old trees) and a lush understory of shrubs and/or herbaceous plants. Many breeding bird species prefer specific successional stages of riparian woodlands. For example, song sparrows, blue grosbeaks, yellow-breasted chats, yellow warblers, and common yellowthroats are often most abundant in early successional habitats (e.g., stands approximately 2 to 4 m [6.5 to 13 ft] tall) with dense vegetation near the ground. Other species, such as Cooper's hawks, red-shouldered hawks, yellow-billed cuckoos, tree swallows, and black-headed grosbeaks, prefer late-successional stands with taller trees and snags (e.g., more than 10 m [33 ft] tall) that are required for nesting substrates and/or song or foraging perches. Some bird species (most woodpeckers, owls, and some swallows and flycatchers) require large snags for nesting (Zeiner et al. 1990a; Riparian Habitat Joint Venture 2004).

Riparian areas also provide essential habitat for migratory birds and wintering species. For example, willow flycatchers (state listed as endangered) require these habitats during spring and fall migration, but they do not remain to nest in western Placer County (Table 6-1). Many other species of Neotropical birds such as vireos, warblers, thrushes, and grosbeaks also depend on riparian habitats for cover and foraging during migration (Riparian Habitat Joint Venture 2004).

Upland Habitat Requirements

Upland habitats provide migratory stopover grounds, foraging habitat, and dispersal corridors for non-breeding adults and juveniles of many riparian-associated species. For this reason, the adjacent land cover is a strong determinant of the species composition of a specific habitat area (Appendices A and B). Yellow-billed cuckoos, yellow warblers, common yellowthroats, and song sparrows are among the many riparian-associated species that may forage in upland habitats adjacent to riparian nesting sites (Zeiner et al. 1990a). Upland areas serve both as refugia during floods and as supplemental or primary foraging areas at other times of year. Riparian areas also can support primarily upland nesting bird species for perching, nesting, foraging, and water (Heath and Ballard 2003). Uplands can also be important for juvenile dispersal. For example, in coastal California, juvenile Swainson's thrushes use uplands regularly during the post-fledgling period (PRBO unpublished data). Swainson's hawk is an example of a species that frequently nests in riparian woodlands in the Central Valley but forages in upland habitats consisting of large, flat, open, undeveloped landscapes with suitable grassland or agricultural foraging habitat. Swainson's hawks usually nest in large native trees such as valley oaks, cottonwoods, and willows, although nonnative trees, such as eucalyptus, are also used (England et al. 1997). Other primarily riparian-associated birds that often forage in adjacent, upland habitats include Cooper's hawks, red-shouldered hawks, tree swallows, blue grosbeaks, and American goldfinches (Table 6-1).

Patch Size and Riparian Width Requirements

Numerous studies in North America have demonstrated that breeding bird species richness and abundance are positively correlated with riparian width and patch size—at least for riparian-associated and forest interior species. The following studies from California, other states, and Canada provide examples of the relationships between riparian width and patch size and bird species richness and abundance.

California

- In the California Central Valley, riparian bird species richness increased with the width of the riparian zone (Stralberg et al. 2004 [Appendix B of this report]). Species richness was positively associated with riparian width along mainstem rivers, but not along smaller, tributary streams, with a significant increase in species richness occurring beyond 100 m (Appendix B).
- Also in the Central Valley, the occurrence of three riparian-associated species (i.e., black-headed grosbeak, common yellowthroat, and yellow warbler) also was positively associated with riparian zone width (Appendix B). Black-headed grosbeak presence was positively associated with riparian width at mainstem, but not tributary sites, while the reverse was true for the yellow warbler and common yellowthroat. For all three species, significant increases in abundance occurred when the riparian zone was greater than 100 m in width (Appendix B).
- In the San Francisco Bay Area, bird species richness and density decreased as the number of artificial structures (i.e., bridges) increased and as the volume of native vegetation decreased due to urbanization (Rottenborn 1999).
- In coastal Marin County, the abundance of warbling vireos, Swainson's thrushes, and common yellowthroats increased with the width of the riparian corridor. There was no association between riparian width and bird species diversity or richness (Holmes et al. 1999).
- In the eastern Sierra, bird species diversity was positively correlated with riparian width and tree species diversity (Heath and Ballard 2003).

- In California, Song Sparrows and Spotted Towhees have been observed in strips as narrow as 1 m, and other species have been observed in strips 10 m wide (Soulé 1988, PRBO unpubl. data).

Other States

- Along Oregon's headwater streams, riparian buffers are likely to provide the most benefit to riparian- and forest-associated birds if they are more than 40 m (131 ft) wide (Hagar 1999).
- In eastern Oregon, total abundance of riparian birds was greater in continuous shrub associations than in discontinuous shrub associations (Sanders and Edge 1998).
- In Texas, bird abundance was positively correlated to forest width, and streamside forests more than 50 m (164 ft) wide supported the greatest number of total species; area-sensitive bird species increased in abundance in these forests as widths increased from 25 to 100 m (82 to 328 ft); and narrow riparian strips were usually inhabited only by species associated with early successional vegetation and habitat edges (Dickson et al. 1995).
- In South Carolina, species richness of all birds (including Neotropical migrant birds) increased with the width of riparian stands. Narrow riparian strips (less than 50 m [164 ft] wide) supported an abundant and diverse avifauna, but conservation of wide strips (more than 500 m [1,640 ft] wide) was required to support the complete avian community characteristic of that region (Kilgo et al. 1998).
- In Iowa, bird species richness increased with the width of wooded riparian habitats (from 10 to 200 m [33 to 656 ft]), and area-sensitive species were only present on the widest plots (Stauffer and Best 1980).
- In Pennsylvania, most area-sensitive bird species did not occur in riparian zones less than 25 m (82 ft) wide. However, the presence of very narrow (e.g., 2 m [7 ft]) bands of woody vegetation along streams was found to be important for some bird species in disturbed areas (Croonquist and Brooks 1993).
- In Maryland and Delaware, the species richness of area-sensitive riparian birds increased in width zones between 25 m (82 ft) and 100 m (328 ft), and several Neotropical migrant species were only found in riparian forests more than 100 m (328 ft) wide (Keller et al. 1993).

Canada

- In Alberta, forest-dependent bird species declined as buffer width narrowed from 200 m (656 ft) to less than 100 m (328 ft) (Hannon et al. 2002).
- In Quebec, riparian strips less than 40 m (131 ft) wide had the highest mean bird densities (Darveau et al. 1995).

- In Newfoundland, total numbers of interior forest birds may increase in wider buffers, but these species were rare even in the widest strips sampled (40–50 m [131–164 ft]) (Whitaker and Montevecchi 1999).

Overall, the species richness (i.e., total number of species) and abundance (i.e., number of individuals within a species) of riparian-associated species are highest in wide and continuous riparian corridors; this pattern is especially true for area-sensitive species. The effect of riparian width depends on each species' needs, the riparian habitat type and its historic conditions, and attributes of the surrounding landscape. Fragmentation of riparian woodlands could be especially detrimental to nonmigratory species such as song sparrows and spotted towhees that generally do not disperse over large distances. Even thin strips of connecting habitat, while usually not suitable for nesting, can benefit sedentary species that will not disperse through open habitats (e.g., grasslands or barren areas) (Croonquist and Brooks 1993).

Patch size requirements for each species depend on territory and home range sizes and relative sensitivity to fragmentation (Tewksbury et al. 1998; Riparian Habitat Joint Venture 2004). In planning the conservation of an assemblage of species, those species with greatest sensitivity to habitat fragmentation should be used to set patch size requirements (Tewksbury et al. 1998). In western Placer County, some of the most area-sensitive bird species are raptors (home ranges often larger than 100 ha [247 ac]), yellow-billed cuckoos (home ranges larger than 10 ha [25 ac]), downy woodpeckers, and yellow-breasted chats (home ranges greater than 1 ha [2.5 ac]). These species require relatively large areas of riparian habitat to breed and forage successfully (Table 6-1).

Yellow-billed cuckoo is an example of a species that requires large tracts of late-successional riparian forest for breeding habitat. This species was a rare historical visitor to western Placer County, but it has not been recorded there in many decades (Jones & Stokes 2004a). However, yellow-billed cuckoos are regular breeders in wide riparian forests along the Sutter Bypass, about 12 km (7.5 mi) from the Placer and Sutter county line. Using radio-telemetry, Laymon and Halterman (1987) determined that yellow-billed cuckoos have large home ranges, averaging 17 ha (42 ac). Optimal stands were defined as more than 80 ha (198 ac) in extent and wider than 600 m (1,970 ft), marginal stands as 20–40 ha (49–99 ac) in extent and 100–200 m (328–656 ft) wide, and unsuitable stands as less than 15 ha (37 ac) in extent and less than 100 m (328 ft) wide Laymon and Halterman (1989).

Effects of Human Alterations on Riparian Birds

Habitat Loss and Degradation

In the western United States, approximately 95% of riparian habitats have been lost or degraded due to human activities during the past 100 years (Smith 1977, Ohmart 1994). These habitats represent less than 1% of most western landscapes, yet they provide breeding habitat for more than 50% of bird species in this region (Ohmart and Anderson 1982; Rice et al. 1983; Ohmart 1994; Tewksbury et al. 2002). Throughout the Central Valley and Sierra Nevada foothills, riparian habitats have been reduced to a small fraction of their original extent (Hunter et al. 1997, Riparian Habitat Joint Venture 2004), and those habitats that remain have been fragmented and degraded by a variety of human activities. The primary factors include historical gold mining; heavy livestock use of some riparian corridors; vegetation removal on the floodplain; introduction and spread of noxious weeds; road and home development; alterations in the hydrologic regime caused by hydroelectric and water storage reservoirs; gravel mining; and groundwater extraction (Kondolf et al. 1996).

In western Placer County, riparian woodlands occur as well-developed and continuous stands along depositional reaches of Coon Creek and portions of the Bear River and the American River. Along most other creeks, however, this habitat occurs as narrow and generally discontinuous bands of trees (Appendix A). Riparian woodlands rarely occur on intermittent streams and almost never on ephemeral streams that only flow during storm events. Riparian vegetation occupies about 2,456 ha (6,069 ac), or roughly 2% of the land area, in western Placer County (Jones & Stokes 2004a). Accordingly, it is clear that available riparian habitat has been greatly reduced and fragmented, causing a decline in locally nesting populations and an increased potential for local extirpation.

Riparian areas in western Placer County are increasingly surrounded by urban, rural-residential, and agricultural development. Increased noise levels associated with human activity can cause nest abandonment, flushing from the nest, and consequent nest failure (Delaney et al. 1999). Agricultural activities such as mowing, disking, grazing, pesticide use, and artificial flooding can also reduce the habitat quality if they encroach into riparian woodlands (Ohmart 1994). Fragmentation and degradation resulting from urban, residential, and agricultural land uses has probably reduced the wildlife habitat functions of most riparian areas in western Placer County (Appendix A; Jones & Stokes 2004a, 2004b). Urban development can also result in increased mammalian and avian predator populations and greater exposure to predation pressures, as discussed below.

The species richness and densities of certain riparian-associated birds have been demonstrated to decrease with increasing urban development in the surrounding landscape (Rottenborn 1999; Miller et al., 2003). In the uplands of Placer County's foothill oak woodland zone, several riparian-associated bird species (including black-headed grosbeak) were found at lower relative abundance in fragmented compared to unfragmented oak woodland landscapes (Stralberg and Williams 2002).

Livestock Grazing

Livestock grazing in riparian areas is particularly widespread in the western U.S., especially in dry areas where cattle are attracted to riparian zones for water, shade, and shelter (Bryant 1979). Many native bird species have experienced population declines in grazed or heavily settled riparian areas (Tewksbury et al. 2002). Cattle browse and trample riparian vegetation, compact the soil, promote stream bank erosion and loss of water quality, and they attract brown-headed cowbirds (see below). Intensive grazing often increases the fragmentation and degradation riparian habitats, and this leads to a reduction of bird species richness and abundance. During the breeding season, grazing can be particularly detrimental to bird species that nest on or near the ground because cattle disturb understory vegetation and may directly trample nests and/or fledglings (Bock et al. 1993).

Brown-Headed Cowbird Brood Parasitism

The brown-headed cowbird is a native North American species that expanded its range into California in the early 1900s (Grinnell and Miller 1944). Brown-headed cowbirds parasitize the nests of other native songbirds and reduce their reproductive success (Rothstein 1975, Beedy and Granholm 1985, Zeiner et al. 1990a, Gaines 1992, Lowther 1993). Cowbird parasitism contributes to lowered productivity in host species through direct destruction of host eggs and competition between cowbird and host chicks. Brown-headed cowbirds usually parasitize songbird nests that are situated near forest edges (Rothstein et al. 1984, Gates and Evans 1998). However, more recent studies suggest proximity to (within 3.2 km [2 mi]) and occurrence of host species is much more important than the presence of habitat edges, especially in western riparian habitats (Tewkbury et al.1999).

Cattle grazing and other livestock operations attract brown-headed cowbirds. Human habitation, agriculture, and livestock facilities adjacent to riparian zones provide brown-headed cowbirds with ample foraging habitat close to songbird breeding grounds (Tewksbury et al. 1998, Riparian Habitat Joint Venture 2004). In riparian woodlands of western Placer County, brown-headed cowbirds are most common in disturbed areas and in early successional stands, especially where livestock are present nearby (Appendix A). Radio telemetry studies have demonstrated that brown-headed cowbirds may move more than 6.7 km (4.2 mi) between foraging and breeding areas (Rothstein et al. 1984). Daily commute distances of 14 k or more have been reported cowbird abundance has also been shown to decline with increasing distance from human food sources over distances as short as 2 to 4 km (1.2 to 2.5 mi) (Curson et al. 2000).

Predation

The number of young fledged is probably the most important factor influencing the occurrence and persistence of many songbird species. For most species, nest success rates of 20% or less indicate unsustainable or *sink* populations (Donovan et al. 1995).

Proximity to urban and agricultural areas typically leads to higher densities of predators subsidized by human activity, such as raccoons, skunks, feral and domestic cats, jays, crows, and magpies, all of which are well-documented avian nest predators (Zeiner et al. 1990a). Nest predation rates are higher in narrow riparian buffer strips than in intact riparian forests (Vander Haegen and Degraff 1996 but see Haff 2003). Nest predation is higher in smaller woodlots and woodlots near suburban areas than in woodlots in rural areas, and survivorship of most bird species is higher in large forested habitats (larger than 35 ha [86 ac]) than in smaller habitat areas (Doherty and Grubb 2002). Open-cup nests more than 2 m (7 ft) above ground are most vulnerable to predation (Wilcove 1985). A dense and diverse herbaceous or shrub understory provides both nesting sites and protection from predators; this vegetative layer is especially important for species such as spotted towhees, song sparrows, and common yellowthroats that nest on or near the ground (Riparian Habitat Joint Venture 2004).

In general, “soft” edges (e.g., wetland or herbaceous cover grading to shrubs or scrubby willow grading to riparian woodland) are preferable to “hard” edges (e.g., abrupt changes in vegetation type such as agricultural or urban development adjacent to stream corridors), because predation levels along hard edges are higher (Suarez et al. 1997). Manicured parks, rural homes, dairies, and urban areas adjacent to riparian habitat can attract predators and be detrimental to riparian bird populations (Miller et al. 2003). Feeding of wildlife, either inadvertently or intentionally, encourages and elevates populations of nest predators such as domestic and feral cats that are estimated to kill many millions of songbirds annually (Stallcup 1991) and have a major impact on local bird populations (Churcher and Lawton 1987, Coleman et al. 1997).

Introduction of Non-native Species

Introduction of Himalayan blackberry in riparian corridors has reduced the extent of native herbaceous and shrub vegetation in riparian woodlands of western Placer County (Appendix A). This species is the dominant understory plant along many riparian corridors. Although it is not native, Himalayan blackberry is used for nesting, food, and cover by many birds (e.g., California quail, song sparrows, spotted towhees, California towhees, common yellowthroats, and tricolored blackbirds) (Jones & Stokes 2004a), and it may have beneficial effects on some species. Other nonnative plants, such as yellow star-thistle, acacia, black locust, and eucalyptus (blue gum), can outcompete native trees and understory plants that are favored by most bird species (Jones & Stokes 2004a).

Introduced birds such as European starlings, house sparrows, and wild turkeys are widespread in riparian areas of western Placer County. Starling populations are thought to be increasing in the Sierra Nevada foothills (Purcell et al. 2002) and occur throughout the oak woodland landscape in Placer County (Stralberg and Williams 2002). Starlings and house sparrows often outcompete native cavity nesters for nest sites, and turkeys consume foods that might otherwise be used by California quail and other native species (Zeiner et al. 1990a; Purcell et al. 2002).

Black rats and Norway rats occur in riparian woodlands of western Placer County; they are common along urbanized streams that are dominated by Himalayan blackberry thickets (Appendix A). Introduced rats may have detrimental effects on nesting songbirds because they prey on eggs and young, and because they often carry and transmit diseases (Zeiner et al. 1990b).

Mammals

Habitat Relationships

Numerous mammal species are abundant in the riparian woodlands of western Placer County. Up to 41 species breed in these habitats; two other species use them for shelter or foraging. No mammal species are proposed for coverage under the HCP/NCCP for the Phase I Planning Area (Jones & Stokes 2004a).

Mammal species that are often associated with riparian woodlands of western Placer County include vagrant shrew, ornate shrew, Trowbridge's shrew, broad-footed mole, Yuma myotis, California myotis, western pipistrelle, big brown bat, hoary bat, Townsend's big-eared bat, and pallid bat, brush rabbit, black-tailed jackrabbit, western gray squirrel, beaver, western harvest mouse, brush mouse, deer mouse, dusky-footed woodrat, California vole, muskrat, western jumping mouse, porcupine, coyote, gray fox, long-tailed weasel, mink, ringtail, raccoon, American badger, western spotted skunk, striped skunk, river otter, mountain lion (visitor), bobcat (visitor), mule deer, and wild pig (introduced). All these species also occur in a variety of upland habitats in western Placer County (Jones & Stokes 2004a).

Riparian Habitat Requirements

Mammals use riparian woodlands for all scales of movement—as part of their territories or home ranges; as dispersal corridors; or for short-distance movements between breeding, resting, and foraging areas. Conservation biologists often recommend preserving riparian areas for mammals with large home ranges in part because such areas can also function as corridors for dispersal of species with smaller home ranges in fragmented landscapes (Brinson et al. 2002). However, if a riparian woodland does not meet a species' habitat requirements, it may not be used for dispersal and hence will not provide a suitable corridor connecting habitat patches for many large mammals (Noss et al. 1996; Rosenberg et al. 1997; Brinson et al. 2002).

Like territories and home ranges, dispersal capabilities differ among vertebrate groups and species. Large mammals move over large distances, while most species of small mammals (except bats) are relatively sedentary and make only short-distance movements.

Some mammals, such as the ornate shrew, Yuma myotis, beaver, ringtail, raccoon, and river otter are strongly associated with riparian corridors in western Placer County (Table 6-1). Riparian woodlands are also important for migratory mule deer that forage, breed, and take cover there. A source of surface water (e.g., creek or river) is especially important to deer (Zeiner et al. 1990b).

Upland Habitat Requirements

As is true of many bird species, many riparian-associated mammals also frequent nearby upland habitats; most use these areas for breeding, foraging, and cover (Table 6-1). Thus, the adjacent land cover is a strong determinant of the species composition of a specific habitat area. In general, riparian areas that are adjacent to agricultural or urban development have fewer native mammals and an increased density of introduced species such as house mouse, Norway rat, and black rat (Jones & Stokes 2004a).

Patch Size and Riparian Width Requirements

Darveau et al. (2001) found that some large mammal species using riparian strips in Quebec seemed to prefer narrower riparian buffers, while other small mammals preferred wider strips.

Thin (e.g., 20 m [66 ft] wide) strips that connect larger patches can be used as refugia by small and larger mammals. However, narrow strips do not provide sufficient habitat to support mammal species with large territories and home ranges, because such strips exhibit high edge-to-interior ratios (Darveau et al. 2001). Riparian strips at least 100 m (328 ft) wide have been recommended to maintain riparian-associated small mammals, because the presence of these species has been observed to change little with increased width (Hannon et al. 2002).

In western Placer County, most small mammals (e.g., shrews, rabbits, ground squirrels, tree squirrels, mice, woodrats) have relatively small territories and home ranges (less than 1 ha [2.5 ac]) (Zeiner et al. 1990b). However, a few species of larger mammals (coyotes, gray foxes, mountain lions, bobcats, mule deer) occupy large areas, and their home ranges may cover many square kilometers, encompassing riparian woodlands and adjacent oak woodlands, annual grasslands, foothill chaparral, and other upland habitats. For this reason, the extent and quality of upland habitats surrounding riparian habitats is especially important in maintaining breeding populations of these species.

Effects of Human Alterations on Riparian Mammals

Habitat Loss and Degradation

The effects of human-induced habitat loss and degradation on riparian mammals are similar to those described above for riparian-associated birds.

Livestock Grazing

Intensive grazing often increases the fragmentation and degradation riparian habitats, and this leads to a reduction of mammal species richness and abundance. Livestock grazing in streams and their associated riparian corridors affect small mammal populations through direct disturbance and alteration of habitat conditions such as loss of cover and reduced food materials (Ehrhart and Hansen 1997).

Predation

Predation resulting from fragmentation (edge and patch effects) causes effects similar to those described above for birds.

Introduction of Nonnative Species

Nonnative mammals (e.g., house mouse, black rat, Norway rat, Virginia opossum) occur in riparian woodlands in western Placer County (Jones & Stokes 2004a), and they often outcompete native small mammals for food, breeding sites, and cover. In general, riparian woodlands that are situated near urbanized or agricultural areas support the highest densities of these species. Feral cats are widespread in riparian woodlands of western Placer County (Jones & Stokes 2004a, Appendix A), and they prey extensively on small native mammals (Zeiner et al. 1990b). Nonnative plants such as Himalayan blackberry provide habitat for black rats and Norway rats that that may compete with or prey upon small mammals in riparian woodlands.

Reptiles and Amphibians

Habitat Relationships

Up to 18 species of reptiles and four amphibians breed in riparian woodlands of western Placer County. Three other amphibian species (California newt, Pacific treefrog, and foothill yellow-legged frog) visit these habitats during some portions of their life cycles. Two riparian-associated reptiles (western pond turtle and giant garter snake) and one amphibian (foothill yellow-legged frog) may be covered under the HCP/NCCP for the Phase I Planning Area.

Amphibian species that occur in riparian woodlands of western Placer County include: ensatina, California slender salamander, Pacific treefrog, foothill yellow-legged frog, and western toad. Reptiles that may occur in these habitats include racer, common garter snake, western terrestrial garter snake, western aquatic garter snake, common kingsnake, night snake, ringneck snake, California whipsnake, gopher snake, western rattlesnake, western and Gilbert's skinks, southern alligator lizard, and western fence lizard (Jones & Stokes 2004a).

Riparian Habitat Requirements

Most amphibians and some reptiles are closely associated with riparian areas and their associated water bodies. Few terrestrial vertebrates are as dependent on water as are amphibians, since these species require surface water to complete their life cycles. Frogs, toads, and salamanders occur in riparian areas year-round, and intact riparian areas, upland habitats, and aquatic breeding habitats are essential for their survival (Brinson et al. 2002). Reptiles use riparian corridors for cover, shade, and a source of water. Microhabitats in riparian areas are important in meeting the habitat requirements of amphibians and reptiles, and dense, shaded forest canopies and leaf litter are positively correlated with the abundance of these species in narrow riparian corridors (Rudolf and Dickson 1990).

Upland Habitat Requirements

Similar to birds and mammals discussed above, many riparian-associated amphibians and reptiles frequent nearby upland habitats, and can use these areas for breeding, foraging, and cover (Table 6-1). Accordingly, the adjacent land cover is a strong determinant of the species composition of a specific habitat area. Upland habitats can serve as important refugia for reptile and amphibian species during times of flooding. Aquatic turtles will use upland habitats, including forests and flooded agricultural areas, during the warm months (Bodie and Semlitsch 2000). Several species of lizards associated with the vegetative cover and organic material of riparian forests bask and forage in uplands (Brinson et al. 2002). Many snake species hunt in upland habitats, but they rest in cooler microclimates under dense riparian forests (Zeiner et al. 1988).

Patch Size and Riparian Width Requirements

Most reptiles and amphibians in western Placer County have relatively small home ranges and territories (less than 1 ha [2.5 ac]) (Table 6-1). For example, Pacific treefrogs often move only about 10 m (33 ft), and western skinks have average home ranges of only about 0.09 ha (0.22 ac) (Zeiner et al. 1988). In contrast, western pond turtles breed along slow-moving, permanent streams, and they deposit eggs in nests in sandy soils up to 100 m (328 ft) from the streams (Zeiner et al. 1988). Similarly, giant garter snakes may migrate long distances (more than 100 m [328 ft]) from wetland habitats to upland sites that serve as winter hibernacula (Zeiner et al. 1988). Semlitsch and Bodie (2003) recommended a three-tiered approach to conserving habitat for riparian-associated amphibians and reptiles: aquatic buffer (30–60 m [98–197 ft]), core habitat (142–289 m [466–948 ft] including aquatic buffer), and terrestrial buffer (additional 50 m [164 ft] beyond the core habitat to account for the needs of most reptile and amphibian species).

Effects of Human Alterations on Riparian Reptiles and Amphibians

Changes in Flows

Flow diversions or increased streamflows in summer due to water supply and/or releases of treated sewage water could possibly affect amphibians by stranding of tadpoles, washing away or desiccating egg masses, or increasing predation. These effects have been documented for salmonids and foothill yellow-legged frogs (Bauersfeld 1978; National Marine Fisheries Service 1994; U.S. Fish and Wildlife Service 1995, 1996; Kupferberg 1996a; Lind et al. 1996). Water diversions for agriculture also have the potential to entrain tadpoles and other amphibian larvae into irrigation ditches, causing direct mortality. In general, flow and depth affect habitat suitability for riparian-associated amphibians, and reduced flows may confine larvae in remaining pools where they are more susceptible to predation (Hayes and Jennings 1986, 1988).

Habitat Loss and Degradation

In general, the effects of anthropogenic habitat loss and degradation on riparian reptiles and amphibians are similar to those described above for riparian-associated birds. However, inputs of fine sediment from adjacent land uses may also detrimentally alter the aquatic habitats of amphibians (Ashton et al. 2003).

Livestock Grazing

Livestock grazing in riparian corridors affects reptile populations through direct disturbance and alteration of habitat conditions. However, these effects may not result in differences in reptile and amphibian species richness or abundance between grazed and ungrazed sites (Homyack and Giuliano 2002).

Predation

Predation as a result of fragmentation (edge and patch effects) probably is greater in agricultural and urbanized areas than in riparian forests surrounded by oak woodlands or other upland habitats. The introduced bullfrog is a major predator of adult and larval amphibians (see discussion below).

Introduction of Nonnative Species

Bullfrogs are the only introduced, nonnative amphibian species in western Placer County. They were observed on about 25% of the riparian plots that were surveyed in the course of this study (Appendix A). Bullfrogs frequently prey on the larvae and adults of native amphibians, and they compete with native amphibians for space and food (Zeiner et al. 1988). Bullfrogs may be responsible for the elimination of California red-legged frogs and foothill yellow-legged frogs from the floor of the Central Valley and much of the Sierra Nevada foothills (Moyle 1973; Kupferberg 1996b). There are no introduced reptiles in western Placer County (Jones & Stokes 2004a).

Relationships Between Setback Width and Effects of Human Alterations

Some effects of human-induced alterations (e.g., abrupt flow changes) do not vary with riparian width, and their effects on terrestrial vertebrates are not well understood. However, many other relationships between riparian area width and animal diversity have been well documented. The effects that are most strongly related to setback width and the total area of riparian plots are direct habitat losses and fragmentation of riparian corridors. Many riparian species require a minimum area of contiguous habitat that must contain specific habitat attributes (e.g., interior forest microclimate, upland refugia, large trees, snags). In order to conserve wildlife habitat functions, the width of riparian areas must be sufficient to contain these habitat attributes for area-sensitive species.

Habitat requirements vary considerably among various riparian-associated vertebrate taxa. However, the following general conclusions can be made regarding the relationship of habitat values to width and size of riparian areas in western Placer County.

- Large (more than 10 ha [25 ac]) and wide (more than 500 m [1,640 ft]) riparian corridors provide the highest habitat values for riparian-dependent wildlife with large home ranges and territories.
- Moderately large (5–10 ha [12–25 ac]) and wide (more than 100 m [328 ft]) corridors provide sufficient habitat values to support most native species that are strongly associated with these habitats.

- Small (less than 5 ha [12 ac]) and narrow (less than 30 m [98 ft]) riparian corridors provide habitat values for many species, but most area-sensitive species will probably not be present.
- Highly fragmented and narrow riparian corridors (< 5 m [16 ft]) provide habitat for only a few generalist species, but they may still provide some values for cover and as movement corridors in urbanized and agricultural areas.

Recommendations for Setbacks to Conserve Terrestrial Animal Functions

In view of the foregoing, the project team recommends the following management strategies to conserve wildlife habitat functions.

- Low order streams (i.e., first and second order stream segments), which typically have narrow riparian corridors, should be managed to maintain and enhance riparian corridors at least 30 m wide. Where only very narrow (e.g., < 5 m [16 ft] wide) riparian corridors are feasible, these narrow areas should still be conserved because they may function as dispersal corridors.
- Higher order stream segments (i.e., third order and higher), which often have broader riparian corridors, should be managed to maintain and enhance riparian corridors at least 100 m (294 ft) on both sides of the channel (Semlitsch and Bodie 2003, Appendix B). Riparian woodlands should be restored and enhanced within this zone. Restoration and enhancement measures should include:
  - Re-creation of regular disturbance events (e.g., high water) on the floodplain will enhance vegetation and breeding bird populations in most systems (Riparian Habitat Joint Venture 2004).
  - Management activities such as mowing, grazing and burning within riparian zones should be limited to the non-breeding season to minimize impacts on nesting birds (Riparian Habitat Joint Venture 2004).
  - Other recommendations listed in (Riparian Habitat Joint Venture 2004).
- Where feasible, contiguous areas larger than 5 ha (12 ac) should be maintained, enhanced and linked to provide habitat refuge areas for area-sensitive species. These areas should be connected by riparian corridors more than 30 m (98 ft) wide on both sides of the channel wherever possible, in order to provide movement and dispersal corridors for wildlife.
- Where large, wide riparian corridors are not feasible in urbanized and/or agricultural settings, a minimum riparian buffer width of 10 m (33 ft) should be maintained to provide movement corridors for generalist species (Riparian Habitat Joint Venture 2004).

- Riparian woodland edges should be minimized (e.g., patches rather than linear strips) and buffered by shrubs and forbs (to reduce predation pressure on open-cup nesting species (RHJV 2004, Small et al. 1999).
- Streams should be prioritized for preservation and/or enhancement based on the information summarized herein. Some streams currently have higher wildlife value than others (e.g., Coon Creek) and should be the conservation priority.
- Non-native plants and animals, especially nest predators (e.g. rats, raccoons, domestic and feral cats), should be reduced and controlled on riparian-adjacent properties (Riparian Habitat Joint Venture 2004).
- The preservation, restoration and linkage of large parcels of undeveloped and uncultivated lands adjacent to riparian areas will provide significant benefits to riparian songbird species. Thus, large contiguous areas of riparian vegetation surrounded by “natural” uplands should be conserved to the greatest extent possible.
- Potential effects of adjacent land uses on riparian areas should be thoroughly evaluated during regional land use planning, and during the environmental review and permitting processes for specific projects, and these effects should be avoided to the maximum extent practicable.

It is important to recognize that riparian setbacks are not sufficient to ensure habitat functions for all wildlife species. Many factors affecting wildlife habitats are unrelated, or only indirectly related, to setbacks; such factors include the condition of the riparian vegetation and the abundance of nonnative plants and animals. Landscape factors can have significant effects on riparian areas (Allan 2004, Appendices A and B of this report). For example, adjacent land uses, such as intensive grazing, human habitation, golf courses, and agriculture, can significantly subsidize predator populations that can then turn to the riparian zone for sustenance (Riparian Habitat Joint Venture 2004).

Currently, most riparian areas in western Placer County have been affected by human alterations. Even where moderately wide sections (i.e., more than 100 m [328 ft]) of riparian vegetation remain, wildlife habitat functions and species richness and abundance may be reduced compared to large and wide riparian corridors that are surrounded by native vegetation (Appendices A and B). Therefore, conservation of wildlife habitat functions in western Placer County’s riparian areas will require the implementation of measures involving the management of adjacent land uses as well as streams and riparian vegetation within defined setbacks.

Chapter 7

Overall Recommendations for Riparian Setbacks

Riparian setbacks should be adequate to provide long-term conservation of riparian and stream functions in western Placer County. However, while width criteria for setbacks are particularly important, other criteria should address the compatibility of existing and future land uses within these setbacks with the conservation of riparian and stream functions. Setbacks are essential for the conservation of riparian and stream functions, but they are not in themselves sufficient to ensure successful conservation of these functions. For this reason, additional measures also will be necessary to conserve these functions.

Conclusions Regarding Riparian and Stream Functions

Based on the review and analysis of riparian and stream functions, the effects of human alterations on such functions, and the relationships between these effects and setback widths, the project team identified the following 10 conclusions that are particularly relevant for setback criteria.

- Stream channels move within their active floodplains.
- Changes in runoff and erosion from uplands affect hydrologic and biogeochemical functions of streams.
- Patterns of groundwater flow affect biogeochemical functions (e.g., nitrate and phosphorus removal, degradation of SOCs); these patterns can be complex in both active and historic floodplains.
- Erosion of sediment is a major pathway by which contaminants enter streams.
- Sediments stored on active floodplains may remain there temporarily until floodwaters carry them into stream channels.
- Periodic floodplain inundation is important for salmonid and riparian plant habitat functions.
- Riparian vegetation is dynamic: it is frequently removed by disturbances, grows rapidly, and is sensitive to water availability.

- All riparian and stream functions are affected by artificial structures, impervious surfaces, ground disturbance, and removal of natural vegetation within stream channels or active floodplains.
- Riparian-associated wildlife species differ in the specific habitat attributes they require in riparian systems. Consequently, structurally diverse vegetation, as well as the full range of naturally occurring physical conditions and disturbance regimes, are necessary to provide suitable riparian habitat for the entire community of associated wildlife species.
- Many riparian-associated wildlife species use, and often require, both riparian and adjacent upland habitats for reproduction, cover, and/or foraging.

Rationale for Including Active Floodplains in Setbacks

These conclusions regarding riparian and stream functions, considered collectively, indicate that most human uses of the active floodplain are not compatible with conservation of riparian functions, because the stream and its floodplain represent an integrated system that, when intact, produces riparian functions. Accordingly, development and encroachment setbacks should include the entire active floodplain of a creek or river. (The active floodplain is the geomorphic surface adjacent to the stream channel that is typically inundated every 2-10 years or less.)

These conclusions also indicate that active floodplain boundaries are more stable and measurable than stream banks or the boundaries of riparian vegetation that are dynamic and change with time. Therefore, the boundary of the active floodplain, which can be readily delineated, is a preferable basis for determining setback widths than are the edges of stream banks, stream centerlines (or thalwegs), or any boundaries based exclusively on channel widths or vegetation.

Rationale for Including Lands Adjacent to Active Floodplains in Setbacks

The conclusions regarding riparian and stream functions indicate that lands adjacent to active floodplains provide physical and habitat functions, and they help to buffer streams from excessive inputs of sediment and contaminants. In general, conservation of most terrestrial wildlife functions depends on the inclusion of land beyond the active floodplain to provide adjacent upland habitats that benefit many riparian-associated wildlife species, and to buffer riparian habitats from the effects of adjacent land uses.

In western Placer County, riparian vegetation currently provides wildlife habitat outside the active floodplains of rivers and creeks. Such vegetation can occur on historic floodplains that have become isolated from streams due to changes in flows and channel form. Construction of levees or berms also causes isolation of riparian vegetation. Some of this adjacent vegetation would be within setbacks that include land outside the active floodplain. Adjacent lands would also buffer riparian and stream ecosystems from inputs of sediments and contaminants through infiltration of runoff and retention of sediment. Along the smallest channels, whose floodplains are very narrow (or essentially absent), this additional buffer is necessary to prevent inputs from entering the stream channel directly.

There is no single, abrupt, well-documented threshold width setback that would provide maximum benefits for all riparian functions. Rather, because riparian functions have different mechanistic bases, they are affected by different site attributes, and the relationship between setback widths and reduction of human effects differs among riparian functions. These relationships are described in detail in Chapters 2-6.

Nevertheless, several defensible arguments can be constructed regarding the appropriate width for a buffer to include within riparian setbacks. First, most riparian functions would be affected if setbacks included a buffer of less than 20 m (66 ft) beyond the active floodplain; consequently, narrower widths are not adequate for long-term conservation of riparian functions. This conclusion is based largely on our review of the scientific literature (summarized in Chapters 2-6). In addition, in western Placer County, stream incision and a discontinuous cover of woody plants reduces the benefits of narrow buffers. Recent incision now restricts the active floodplain to a narrow band along many of the higher order stream segments in western Placer County (Jones & Stokes 2004c, Placer County Planning Department 2002). Thus, a narrow setback would not include large areas of riparian vegetation on the historical floodplain. Also, the riparian vegetation of western Placer County has a lower and more discontinuous cover of trees and shrubs than do many of the sites where research has been conducted (Appendix A). For many functions (e.g., cover for terrestrial wildlife), this variability in vegetation extent and structure reduces the effectiveness of narrow setbacks.

Second, while there is evidence that even buffers wider than 30 m (98 ft) are not sufficient to eliminate detrimental effects altogether, the benefits provided by additional width beyond 30 m (98 ft) are either small or represent diminishing returns for most functions. For example, in western Placer County, riparian (and most upland) trees reach only 20-30 m (66-98 ft) in height. Thus, at distances > 30 m (98 ft) trees provide very little woody debris to stream ecosystems, and cast little shade on streams.

Third, unlike most other functions, the conservation of wildlife habitat functions for some area-sensitive species requires buffer areas substantially wider than 30 m (98 ft) beyond the active floodplain. This is illustrated by the summary in Table 6-1 of the habitat requirements and area requirements of riparian-associated wildlife in western Placer County. Significantly, wildlife habitat functions also differ from most other functions because the setbacks necessary to conserve them do not necessarily have to be applied along the entire stream network in order to be beneficial. Most wildlife habitat functions probably could be conserved in western Placer County by means of extensive sites with wider setbacks (> 100 m [328 ft]) connected by stream corridors with narrower setbacks (e.g., 30 m [98 ft]).

Recommendations for Riparian Setback Widths in Western Placer County

The project team's overall recommendations for riparian setbacks are presented below.

- Apply to first and second order stream segments a minimum riparian setback that includes the entire active floodplain plus a buffer of 30 m (98 ft) of adjacent land (on each side of the active floodplain), or the distance to the nearest ridgeline or watershed boundary, whichever is less. (First order stream segments are upstream segments that have no tributaries, and second order segments are formed by the junction of first order segments.) Though the purpose of this setback would be to conserve stream and riparian functions; it would not be sufficient for the conservation of many wildlife species with large area requirements.
- Along higher order stream segments (i.e., third order and greater), and along lower order segments at selected sites (e.g., those in or adjacent to conservation lands), apply a setback of at least 100 m (328 ft), and preferably 150 m (656 ft), from the active floodplain for the purpose of conserving and enhancing stream and riparian ecosystem functions including most wildlife habitat functions. Along these larger stream segments, floodplains and riparian areas are more extensive, continuous, and structurally diverse than for lower order stream segments (e.g., first and second order). These areas constitute corridors connecting a watershed's lower order stream segments, and, at a watershed scale, the riparian areas of these higher order segments contain particularly important habitats for most riparian-associated species. The conservation of wildlife habitat functions within these areas may be necessary for the persistence of their populations within western Placer County. For this reason, a wider setback, sufficient for the retention of wildlife habitat functions, is recommended along these stream segments.

The team estimates that these recommendations would result in a total setback width ranging from slightly more than 30 m (98 ft) on most first- and second-order stream segments to over 150-200 m (492-656 ft) on higher-order streams near Placer County's western boundary. (Widths > 150 m (656 ft) would be associated with the 150 m setback suggested for higher order stream segments in the overall recommendation above.) This estimate is based on a preliminary examination of riparian vegetation as shown on aerial photographs and of mapped alluvial soils; such soils indicate the extent of the historic floodplain, which in many cases is wider than the current active floodplain. The project team did not measure active floodplains in the field. However, widespread incision limits active floodplains to a fraction of the historical floodplain of along several of the larger streams (Jones & Stokes 2004c, Placer County Planning Department 2002).

By basing these recommendations, in part, on the width of active floodplains, the project team has created a variable, site-specific setback width that accounts for stream size. The width of the active floodplain provides a clear, functional basis for a variable width criterion that accomplishes the same purpose more directly than criteria based on stream order, slope, and other attributes of streams and their settings.

Management Recommendations for Riparian Setbacks

Within these setbacks, most developed land uses would be incompatible with the conservation of stream and riparian functions. Within the active floodplain, developed land uses should be restricted to unavoidable crossings by roads and other infrastructure, because any structures or alterations of topography, vegetation or the soil surface are likely to affect both stream and riparian functions, and could result in substantial effects both on-site and downstream.

Within the portion of a setback that is outside of the active floodplain, some uses could be compatible with conservation of riparian functions, particularly along first- and second-order streams where conservation of salmonid and wildlife habitat are not necessarily the primary objectives. Along first- and perhaps second-order streams, compatible agricultural uses include filter strips and riparian buffers managed according to standards established by the National Resources Conservation Service. Such practices would improve the buffers' effectiveness for conserving some functions; additionally, there are programs that subsidize the establishment and maintenance of such practices. Along first- and perhaps second-order streams, compatible developed land uses could include public open space, landscaping, and low-density residential development, provided that no impervious surfaces, infrastructure, or irrigation are placed within the setback.

Within the wider setbacks for wildlife conservation, some additional development > 30 m (98 ft) from the active floodplain could be incorporated at sites with limited conservation value. Though development within these setbacks generally is not compatible with the conservation of wildlife habitats, extensive areas of developed and agricultural lands already exist along streams in western Placer County. Thus, effective conservation of some sites may be very problematic, and it may be more appropriate to mitigate offsite for the loss of habitat caused by development of these sites, than to preclude this development (and thus potentially cause the loss of habitats elsewhere). Such mitigation could contribute to the conservation of more extensive areas along relatively unaltered stream reaches.

In the absence of additional site-specific information, effects on riparian wildlife habitats due to adjacent development could be considered to diminish with distance from the active floodplain or existing riparian area. Effects would be greatest due to development of immediately adjacent land and would drop to minimal levels at 100-200 m (328-656 ft) away. There are several reasons for considering effects to be related to distance. First, the magnitude of effects on the processes sustaining riparian habitats diminishes with distance. Second, most riparian-associated wildlife species also use upland habitats and the area of adjacent uplands is greater when development is more distant. Third, harm and harassment due to pets and people probably diminishes with distance. Fourth, roads and structures are less likely to affect animal movements along the riparian corridor if at a greater distance from it. These and other relevant mechanisms are described in detail in Chapters 2-6 of this report.

Currently, agricultural and developed land uses exist within the recommended setbacks, and they preclude the effectiveness of the recommended setbacks in these areas. For example, along the major streams of western Placer County, approximately a quarter of the land < 20 m (66 ft) from the centerline of a stream, already is in developed or agricultural land-cover (Jones & Stokes 2004a, 2004b). For some functions (e.g., biogeochemical and hydrologic functions), this limitation cannot be offset by establishing wider setbacks in other areas (Weller et al. 1998).

In addition, there are other, more fundamental limitations on the effectiveness of setbacks for conserving riparian and stream functions. Examples of these limitations include the effects of dams and flow diversions, currently abundant nonnative species, mercury from the Gold Rush era already in riparian and stream sediments, and runoff that bypasses riparian areas by passing through the stormwater system directly into streams. Also, conversion of large portions of a watershed or region to developed and agricultural land uses is associated with broad negative effects on riparian and stream ecosystems (Findlay and Houlahan 1996, Roth et al 1996, Booth and Jackson 1997, Magee et al. 1999, Doyle et al. 2000, Paul and Meyer 2001, Allan 2004, Hatt et al. 2004, Pellet et al. 2004, Wissmar et al 2004, and Appendices A and B of this report).

Addressing these and other effects on riparian and stream functions will require additional conservation measures. These additional measures include measures for the:

- design and operation of stormwater and water supply systems to minimize impacts on hydrologic and geomorphic functions;
- implementation of construction and agricultural Best Management Practices (i.e., BMPs) to prevent excessive erosion and high inputs of fine sediments to floodplains and streams.

- maintenance and enhancement of riparian vegetation and it's habitat values (as described in Chapter 6); and
- preservation of extensive areas of natural vegetation, particularly in and adjacent to riparian corridors.

The implementation of such measures would both complement, and greatly enhance, the benefits provided by riparian setbacks for the conservation of stream and riparian functions.

Chapter 8
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Appendix A

Relationships Among Animal Species and Site Attributes in Riparian Ecosystems of the Sacramento Valley, California

Relationships Among Animal Species and Site Attributes in Riparian Ecosystems of the Sacramento Valley, California

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Contents

Tables and Figures

Summary

This report summarizes the relationships between riparian site attributes and biodiversity in the data sets collected in Tasks 2.8 (Evaluation of Habitat Assessment) and 2.10 (Validate RAP and Habitat Assessment) for the Placer County Riparian Ecosystem Assessment. More specifically, for one-hectare (2.5 acres) plots located in riparian corridors of the Sacramento Valley and adjacent foothills, we describe the relationships between species richness (i.e., number of species) of selected taxonomic groups (i.e., birds, mammals, reptiles, amphibians, butterflies, dragonflies, and damselflies) and measured vegetation and land cover attributes. The primary goals for collecting and analyzing these data were to support the development of a functional assessment model (FAM) for riparian habitats in Placer County, and to provide setback guidance for riparian corridors in western Placer County. The key results of the study were:

- vertebrate data from multiple site surveys provide a much stronger basis for assessing a riparian site than do data from a single site visit;
- non-destructive area searches for mammals, amphibians, and reptiles were not effective rapid assessment survey techniques, even with the placement of cover boards to provide artificial shelter for these species;
- for the 50 riparian sites surveyed, species richness was not strongly correlated among the different taxonomic groups, nor was the width or structure of the riparian vegetation strongly correlated with richness for any taxonomic group; however
- land cover in the vicinity (i.e., within 250 meters to 5 kilometers) of plots was related to the species richness of several taxonomic groups we examined, and in some cases, these relationships were strong.

These results have implications for the development of a riparian FAM and for guidance regarding riparian setbacks. However, they should be interpreted with caution since they were based on a small sample size (e.g., only 12 plots were visited for multiple surveys), a large geographic area was covered, and only presence data were collected for species in each taxonomic group. (In addition, several published studies are not consistent with some of our conclusions.) Assessment of overall riparian habitat functions should not be based on a single taxonomic group because none indicates the overall habitat functions provided by a site and responses vary within each taxonomic group. Also, assessments of habitat values should consider, attributes of surrounding land cover, in addition to attributes of the riparian vegetation itself. Similarly, the basis for setback widths should consider the upland habitat requirements of riparian species and the effects of adjacent upland land uses on riparian habitat, as these factors have

significant relationships with species richness of riparian-associated species for at least several taxonomic groups (e.g., birds, dragonflies, and butterflies). Separate technical reports will propose a draft FAM and will provide guidance regarding riparian setbacks. The implications of this study will be considered more fully in these reports.

Relationships Among Animal Species and Site Attributes in Riparian Ecosystems of the Sacramento Valley, California

Introduction

This report summarizes the results of Tasks 2.8 (Evaluation of Habitat Assessment) and 2.10 (Validate RAP and Habitat Assessment) of the Riparian Ecosystem Assessment that Jones & Stokes is conducting for the Placer County Planning Department, with assistance from the Point Reyes Bird Observatory (PRBO). These tasks were intended to support development of assessment techniques, preparation of a functional assessment model (FAM) and summarizing setback guidance for the riparian corridors of western Placer County. These tasks involved collection of data on species presence and site attributes at a random sample of riparian sites in Placer County and throughout the Sacramento Valley. Task 2.8 consisted of a field and geographic information systems (GIS) assessment of 47 sites. Task 2.10 consisted of additional, more intensive, data collection (including multiple surveys) at 12 of these sites.

Our analyses of these data focused on the relationships typically serving as the basis for setbacks and indicator-based assessments. Some FAMs base their measures of terrestrial habitat functions on the presence of selected taxa (e.g., bird species) that are presumed to indicate habitat suitability for other taxonomic groups. However, most FAMs are based on a combination of site attributes that are predicted to influence habitat area or quality for most species. The widths of riparian setbacks that are intended to conserve habitat functions are based on the relationships between species presence and the area of habitat types and the potential influence of adjacent land uses. Therefore, we examined criteria for assessments and setbacks by comparing the relationships among the species richness of taxonomic groups and their relationships to measured site attributes. Our general hypotheses were:

1. The number of riparian–associated bird species (riparian bird species richness) is positively associated with the species richness of other vertebrates and of invertebrates (i.e., bird species richness is a valid indicator of overall biodiversity);

For all taxonomic groups:

2. Species richness increases with the width of riparian vegetation;

3. Species richness increases with the cover of woody plants (i.e., trees and shrubs) in the riparian vegetation;
4. Species richness increases with the total area of riparian vegetation in a plot and its surrounding landscape;
5. Species richness increases with the proportion of surrounding land area in natural vegetation; and
6. Species richness is negatively associated with the proportion of developed and agricultural land uses in the surrounding landscape.

For our analysis of birds and butterflies, we included only riparian-associated species, which are presumably more responsive to riparian site attributes than other species that may use a range of habitat types, including riparian. We considered riparian-associated birds and butterflies to be those species that in the Sacramento Valley and adjacent foothills are primarily associated with riparian vegetation (Tables 1 and 2). These lists were determined prior to field work on the basis of relevant literature (Pool and Gill 1990–2003) and our professional judgments; the draft bird list also was revised in response to comments by PRBO ornithologists.

Methods

In addition to the following summary, our sample design and data collection methods were described (in more detail) in the sample design memo and field protocols provided to the Placer County Planning Department in 2003 (Appendix A).

Sample Design

Study site locations (plots) were a stratified random sample of existing PRBO point count survey sites along tributary streams in the Sacramento Valley where information regarding riparian corridor width was available and site access was know to be possible. Additional plots in Placer County were also included in cases where permission to enter private lands had been granted. Although not along a tributary stream, PRBO sites along the Cosumnes River were included in the list of potential plots because this area was considered reasonably similar to many of the included tributary streams in its riparian attributes. This set of potential plots was stratified on the basis of riparian corridor width. Data from PRBO records, digital aerial photographs, and a draft land cover map of Placer County were used to assign each plot to a width category. These categories were: 0–20 meters (m), >20–40 m, >40–60 m, >60–100 m, and >100–200 m. From each width category, ten plots were randomly selected, each at least 500 m from all other selected plots.

Sample size was limited by access to suitable survey sites and the available budget. On this basis, we estimated the maximum sample size would be 50 plots.

The power associated with this sample was sufficient to identify correlations between variables (power > 0.8 for even small values of *r*); however, it was of more marginal size for the application of multivariate analyses, such as multiple regression analyses. Statistical power is the ability of a statistical test to the identify relationships and differences that exist (i.e., it is the ability to reject the null hypothesis of no difference or association when it is incorrect).

From those plots located on Placer County, public or Nature Conservancy properties, 12 were randomly selected as more intensive data collection plots, each at least 5 kilometers (km) apart. At these plots, in addition to the data collection taking place at other plots, the following surveys were performed: small mammal trapping; placement of cover boards that might be used as artificial shelters for amphibians and reptiles; and multiple surveys for butterflies and vertebrate groups. These data collection plots were included in the study, despite their cost, to allow the value of this additional data to be evaluated. However, for these additional data, the small sample size substantially limits the analyses that can be applied, the power of these analyses, and thus the conclusions that can be drawn from the data. For example, the power associated with data from these 12 plots was only sufficient for the identification of strong correlations (i.e., *r* values > 0.7), and important combinations of site attributes had few or no replicates.

During our study, access or scheduling difficulties prevented most data collection at three plots, and seven plots were not surveyed for odonates. Thus, sample sizes were reduced to $n = 47$ and to $n = 43$ for odonates.

Field Data Collection

A 1-ha plot (100 m by 100 m) was located along the bank of the stream channel at all of the study sites. These plots contained riparian vegetation, and most also contained other natural, or agricultural or developed land-cover. For each plot, information on site attributes was recorded and area searches were conducted for vertebrate and invertebrate species.

The site attributes recorded in the field included: onsite infrastructure, disturbance, vegetation, surrounding land use, and evidence of overbank flows (Appendix A). Presence of infrastructure (roads, bridges, levees, or bank protection) and evidence of disturbance (grazing, trash dumping, cutting of trees and shrubs, etc.) were recorded for the riparian and non-riparian portions of the plot and for lands within 250 m of the plot. (The riparian portion of the plot was defined as the zone covered by riparian trees and shrubs.) For the riparian vegetation within the plot, we recorded its width along the stream (at the plot's edges and center), cover of the tree, shrub and herb layers, and the cover of each woody species, as well as snag density, and predominant tree size class. We also recorded the length and continuity of riparian vegetation along the stream corridor, and estimated the percent of adjacent land (within 250 m) that was in natural vegetation, agricultural, and developed land cover types.

Standardized, time-constrained area searches (Ralph et al. 1993) were conducted separately for vertebrate and invertebrate species (see Appendix A for protocols). For vertebrates, searches of the entire plot were conducted for one hour (between 6 and 11 a.m.) on one day between mid-May and mid-June, 2003. However, at 12 intensive data collection plots we conducted area searches four times at approximately one-week intervals from mid-May to July 1. During the area searches, we recorded all species observed, and species for which scat or tracks were observed, and noted whether the species was observed in the riparian or non-riparian portions of the plot. Woody debris and rocks were not disturbed to avoid degrading habitat. For birds, we also recorded total numbers of individuals and observed behaviors (e.g., territorial displays, carrying food or nesting material, or observation of nests). Observed behaviors (and presence of nests or fledglings) were used to identify potential residents, and the number of potential resident species among riparian-associated birds was included in the analysis. Point counts (Point Reyes Bird Observatory 2003) also were conducted at plots in Placer County because no PRBO point count data existed for those locations.

Each plot was also surveyed twice for butterfly species, once during May 15–30 and again during June 2–14, 2003 and most plots (43 of 47) were surveyed once for odonates (i.e., dragonflies and damselflies) during August 19-29, 2003. These searches were conducted between 9 a.m. and 4 p.m. because of the daily flight activity patterns of these animals. As with the vertebrate area searches, the odonate and first butterfly surveys at each site were one hour long and each observed species was recorded. For butterflies, the number of observed individuals also was recorded. Based on the results of the first butterfly survey and to reduce costs, the second survey at each site was shortened to 50 minutes. (This caused no complications for the testing of our hypotheses because each site received equal survey effort.)

Small mammal live-trapping was also conducted at the 12 intensive data collection sites. Along the length of the plot's streambank side, 15 Sherman live traps were evenly spaced. An additional 15 traps were placed along a second line 10 m away and parallel to the first trap line. Each trap was baited with peanut butter and rolled oats, and a wad of cotton was placed at the back of each trap for bedding. These traps were set within 2 hours of sunset and checked within 3 hours of sunrise on three consecutive nights between June 10 and July 3, 2003.

At the 12 intensive data collection sites, cover boards also were placed within plots (Fellers and Drost 1994). These cover boards were approximately 0.9-m by 0.6 m pieces of 1.9 centimeters (cm) thick plywood. Along the length of the plot's streambank side, 10 cover boards were evenly spaced. An additional 10 boards were placed along a second line 10 m away and parallel to the first. These boards were lifted during each area search to determine the presence of amphibians and reptiles.

Geographic Information Systems Data Collection

In addition to site attributes recorded in the field, GIS data layers were used to estimate the area of four land cover types within 250 m, 1 km, and 5 km of each plot center including: riparian vegetation, natural vegetation (including riparian), developed, and agricultural land cover types. For this analysis, we used the best available data for each plot's location in the Sacramento Valley. These land cover data were from the California Department of Fish and Game's Wetland and Riparian GIS Mapping Layers (Ducks Unlimited 1997), Sacramento River riparian vegetation (California Sate University Chico 1998), U.S. Forest Service existing vegetation (U.S. Forest Service 1999–2000), California Department of Water Resources' land use layer (California Department of Water Resources various years), and the Draft Land Cover Map of Western Placer County (Jones & Stokes 2004). The process by which a single coverage was produced from these data sources involved converting each data source from its vector format to a 31 m grid. For tabulating the area of riparian vegetation within 250 m, 1 km and 5 km, cells attributed as riparian in any of the data layers were counted as riparian. Surrounding land use information was calculated from the California Department of Water Resources land use layer. This layer was a composite of counties that were photographed and mapped in different years. The land use categories in this layer were aggregated into three broad categories: natural vegetation, and agricultural and developed lands.

Data Analysis

Our data analysis consisted of summarizing the data sets and testing our six general research hypotheses. In evaluating these hypotheses, we used scatter plots, correlation coefficients, and simple or multiple stepwise regression models (Sokal and Rolf 1994). All statistical analyses were performed with the S-Plus statistical software package (MathSoft, Inc. 1999).

We evaluated our hypotheses with respect to eight species groups: 1) All bird species; 2) Riparian-associated bird species; 3) All mammals; 4) Small mammals; 5) All amphibians and reptiles; 6) All butterflies; 7) Riparian-associated butterflies; and 8) all odonates. For all of these groups (except small mammals), species richness (i.e., number of species) was used as the measure of the habitat provided for that group at an individual site. In other words, species richness was analyzed with respect to the amount, quality and diversity of habitat. Density of trapped individuals was the metric used for small mammals.

Our conclusions were based on the results of these analyses, consideration of the data's limitations (due to methodology and sample size) and a review of applicable scientific literature.

Table 1. Riparian-Associated Birds of Western Placer County

Common Name	Scientific Name
Cooper's Hawk	*Accipiter cooperii*
Red-shouldered Hawk	*Buteo lineatus*
Swainson's Hawk	*Buteo swainsoni*
Black-chinned Hummingbird	*Archilochus alexandri*
Downy Woodpecker	*Picoides pubescens*
Western Wood Pewee	*Contopus sordidulus*
Willow Flycatcher	*Empidonax traillii*
Pacific-slope Flycatcher	*Empidonax difficilis*
Warbling Vireo	*Vireo gilvus*
Tree Swallow	*Tachycineta bicolor*
House Wren	*Troglodytes aedon*
Yellow Warbler	*Dendroica petechia*
Common Yellowthroat	*Geothlypis trichas*
Yellow-breasted Chat	*Icteria virens*
Song Sparrow	*Melospiza melodia*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Blue Grosbeak	*Guiraca caerulea*
American Goldfinch	*Carduelis tristis*

Table 2. Riparian-Associated Butterfly Species

Common Name	Scientific Name
Sara Orange-tip	*Anthocaris sara*
Pipevine Swallowtail	*Battus philenor*
Lorquin's Admiral	*Limentis lorquini*
Mourning Cloak	*Nymphalis antiopa*
Two-tailed Swallowtail	*Papilio multicaudatus*
Western Tiger	*Papilio rutulus*
Umber Skipper	*Paratrytone melane*
Green-veined White	*Pieris napi*
Satyr Comma	*Polygonia satyrus*
Sylvan Hairstreak	*Satyrium sylvinus*
Red Admiral	*Vanessa atalanta*
California Dogface	*Zerene eurydice*

Prior to calculating correlation coefficients or constructing regression models, variables were transformed to improve normality and homogeneity of variances. Percents were arcsine transformed, areas and widths were log transformed, and count data were square root transformed (Sokal and Rolf 1994; Zar 1999). Correlation coefficients were used to evaluate the magnitude and significance of relationships between pairs of variables. (Magnitude is the degree that two variables co-vary, while significance indicates that the correspondence is unlikely to have occurred by chance.) We used these coefficients to evaluate relationships among plot attributes, the different species groups, and between species groups and plot attributes.

Regression models were also used to evaluate the strengths of relationships between plot attributes and the measured species richness of taxonomic groups. A least-squares regression model is the equation for the straight line that best "fits" the data. This is the line that comes as close to passing through the data points as is possible. Unlike correlation coefficients, regression models can be used to quantify the degree to which combinations of readily observed plot attributes could be considered predictors of species richness. The interpretation of each regression model was based on its R^2 value and the partitioning of the sum of squares among variables (i.e., the sum of the squared deviations from the mean). In developing a regression model for each species group, species richness was the dependent variable and 1–4 plot attributes were the independent variables considered. Only variables significantly correlated with a group's species richness ($\alpha = 0.05$) were considered for initial inclusion in a model. When two or three variables representing an adjacent land cover type (e.g., percent natural vegetation within 250 m and within 1 km) were correlated with a species group, only the variable with the highest correlation was included. This was done to avoid including strongly correlated independent variables that could complicate interpretation of the results. Stepwise multiple regression analysis was used to define the final regression model if two or more variables were included in the initial model.

In interpreting the statistical significance of relationships, we adjusted the threshold for significance to account for making multiple statistical comparisons to evaluate one research hypothesis. Traditionally, a P value < 0.05 is used to indicate statistical significance. However, as more statistical tests are performed the odds of encountering a low P value due to chance increase. Therefore, we adjusted the P value considered significant through a Bonferroni correction (Sokal and Rolf 1994) so that the probability of erroneously considering a result significant (i.e., when the pattern was due to random variation in the absence of an actual relationship) was < 0.05 for the entire set of statistical tests addressing one of our general research hypotheses. Each of our hypotheses was addressed by 8–24 statistical comparisons, therefore, P values of 0.0063–0.0021, respectively, were considered the thresholds for significant relationships. Since Bonferroni adjustments are sometimes criticized as being overly strict, especially when the consequences of false negatives (β error) are worse that the consequences of false positives (α error), P values above these thresholds but < 0.01 were considered suggestive of possible relationships among the variables.

Although more than one dependent variable (i.e., richness based on one or four site surveys) was analyzed for several of the species groups, not every variable was used to evaluate any one of our research hypotheses. Because few mammal, amphibian or reptile species were detected over the course of a single area search, we only used richness based on four visits for these species groups.

Results

Most of the plots were situated in moderately to substantially altered riparian corridors, including Placer County plots (Table 3, Appendix B). At only 2 of the 47 plots (4%) was riparian vegetation > 100 m wide. Only 6 of the 47 plots (13%) were completely surrounded by natural vegetation and did not contain any infrastructure. In contrast, for 16 plots (34%) agricultural or developed land accounted for over half the adjacent land cover within 250 m, and 44% contained a road or other infrastructure (Table 3). On average, agricultural or developed lands accounted for 43% of the lands within 1 km of the plots (Table 4).

The riparian vegetation within most survey plots also was somewhat altered in its composition and structure. In general, the tree layer was discontinuous and averaged only 46% cover, and the shrub layer also had a comparable cover (Table 4). Willows and Fremont's cottonwood accounted for just 16% of tree cover, and oak species (primarily interior live oak and valley oak) accounted for 26%. Non-native species occupied little of this tree layer (5%), but Northern California black walnut, a species absent from this region 150 years ago, accounted for an additional 4% of total tree cover. In the shrub layer, the non-native Himalayan blackberry accounted for over half of all shrub cover.

Table 3. Presence of Infrastructure and Evidence of Disturbance in Plots[1]

Attribute	Total *N = 47*	Placer County Plots *N = 23*	Plots Outside Placer Co. *N = 24*
Presence of Bank Protection	4	5	4
Levee or Berm	15	4	25
Road in Plot	46	50	42
Stream Incision	61	55	67
Evidence of Overbank Flow	57	41	71
Evidence of Grazing	21	17	25
Evidence of Tree Cutting	0	0	0
Evidence of Brush Clearing	4	4	4
Evidence of Dumping	21	22	21
Evidence of Other Disturbance	13	17	8

Note:
[1] Values in table are percents.

Table 4. Summary of Plot Vegetation and Surrounding Land Cover[1,2]

Attribute	Total Mean (Range)	Placer County Mean (Range)	Outside Placer County Mean (Range)
Riparian Width (meters [m])[3]	37 (2–200)	25 (2–80)	49 (10–200)
Tree Cover (%)	46 (3–95)	48 (3–95)	44 (10–80)
Shrub Cover (%)	41 (1–90)	38 (1–80)	44 (2–90)
Herb Cover (%)	76 (10–100)	84 (10–98)	69 (10–100)
Riparian Vegetation 250 m (hectares [ha])	5 (0–13)	4 (0–9)	6 (0–13)
Riparian Vegetation 1 kilometers (km) (ha)	36 (0–147)	26 (0–74)	45 (0–147)
Riparian Vegetation 5 km (ha)	365 (33–1,001)	261 (132–554)	465 (33–1,001)
Natural Vegetation 250 m (%)	66 (0–100)	69 (0–100)	64 (18–100)
Natural Vegetation 1 km (%)	58 (6–100)	59 (6–23)	56 (10–100)
Natural Vegetation 5 km (%)	60 (8–100)	63 (25–91)	57 (8–100)
Agricultural Land Cover 250 m (%)	20 (0–81)	10 (0–68)	28 (0–81)
Agricultural Land Cover 1 km (%)	29 (0–87)	18 (0–62)	39 (0–87)
Agricultural Land Cover 5 km (%)	26 (0–88)	15 (0–49)	37 (0–88)
Developed Land Cover 250 m (%)	14 (0–100)	20 (0–100)	8 (0–81)
Developed Land Cover 1 km (%)	14 (0–49)	23 (0–94)	5 (0–26)
Developed Land Cover 5 km (%)	14 (0–73)	22 (0–73)	5 (0–26)

Notes:

[1] *N* = 47.

[2] Riparian width, and tree, shrub and herb covers are ground-based measurements and land-cover variables are geographic information systems (GIS)–based.

[3] SD = standard deviation.

[4] Sample was stratified by anticipated riparian width, thus these width statistics are not representative of riparian vegetation width in the Sacramento Valley (e.g., the Valley's mean width is narrower).

The six relatively unaltered plots (i.e., no infrastructure in plot and no agricultural or developed land within 250 m) varied widely in their vegetation structure and species composition. The width of their riparian vegetation ranged from 8 m to 200 m. In the tree layer, the cover of oak species ranged from 0 to 78% and the cover of willows and cottonwood from 0 to 30%. The shrub layer varied from over 80% Himalayan blackberry (*Rubus discolor*) to a sparse cover (5%) of shrubs and tree saplings. With the exception of tree cover, these relatively unaltered plots bracketed the range of conditions observed in other plots that were more altered. None of the unaltered plots had low tree covers (range 40-80%); in contrast, 49% of other plots had tree covers below 40%.

There were relatively few strong relationships among site attributes (Table 5); however, suggestive positive relationships existed among riparian vegetation width with tree and shrub cover. Otherwise, most negative relationships were between variables that are inversely related by definition (e.g., land cover proportion) and most positive relationships were between variables that represented the same land cover category at different scales (e.g., developed land within 250 m, 1 km and 5 km).

Data collected at the 12 intensive data collection sites varied in their value for assessing riparian habitats. At these sties, almost no amphibians or reptiles were found beneath the cover boards. The results of the small mammal trapping varied substantially among sites (Table 6, Appendix B), and they did not correspond closely to the results of surveys for other taxonomic groups. However, conducting area searches for vertebrates on multiple dates resulted in more complete species lists (i.e., greater species richness) compared to lists based on a single area search, and species richness estimates based on multiple surveys had stronger relationships to site attributes than single survey estimates (Tables 7 and 8, Figure 1).

Three of the relatively unaltered plots were intensive data collection sites, and at these plots, results were similar to those at more altered sites, with the exception of small mammal density and the number of potential nesting bird species. The total number of small mammals trapped at the unaltered sites averaged 32 ± 4 (mean ± standard error) versus 3 ± 1 at the more altered plots. The number of potential nesting bird species at the unaltered sites averaged 3.3 ± 0.3 versus 1.1 ± 0.4 at the other plots (Table 6).

Table 5. Correlations Among Plot Attributes[1,2]

	Riparian Width	Tree Cover	Shrub Cover	Riparian (250 m)	Riparian (1 km)	Riparian (5 km)	Natural (250 m)	Natural (1 km)	Natural (5 km)	Agricultural (250 m)	Agricultural (1 km)	Agricultural (5 km)	Developed (250 m)	Developed (1 km)	Developed (5 km)
Riparian Width	1.00	**0.48**	**0.44**	0.30	-0.01	-0.04	0.04	**0.43**	0.01	0.13	-0.28	-0.17	-0.14	-0.16	0.19
Tree Cover	–	1.00	**0.44**	0.03	0.03	-0.04	-0.07	-0.06	-0.05	0.05	-0.01	-0.06	0.05	0.13	0.18
Shrub Cover	–	–	1.00	-0.18	-0.12	-0.04	-0.13	-0.01	0.16	-0.07	-0.08	-0.02	0.26	0.17	-0.10
Riparian (250 m)	–	–	–	1.00	**0.91**	**0.63**	-0.21	-0.21	-0.04	0.24	0.28	0.15	0.01	-0.03	-0.08
Riparian (1 km)	–	–	–	–	1.00	**0.73**	-0.29	-0.26	-0.06	0.28	0.27	0.13	0.06	0.04	-0.05
Riparian (5 km)	–	–	–	–	–	1.00	-0.29	-0.27	-0.03	0.28	0.20	0.02	0.07	0.13	0.04
Natural (250 m)	–	–	–	–	–	–	1.00	**0.84**	**0.59**	**-0.55**	**-0.44**	**-0.37**	**-0.59**	**-0.49**	-0.20
Natural (1 km)	–	–	–	–	–	–	–	1.00	**0.74**	**-0.53**	**-0.65**	**-0.55**	**-0.44**	**-0.42**	-0.11
Natural (5 km)	–	–	–	–	–	–	–	–	1.00	**-0.48**	**-0.54**	**-0.61**	-0.21	-0.23	-0.30
Agricultural (250 m)	–	–	–	–	–	–	–	–	–	1.00	**0.83**	**0.68**	**-0.34**	**-0.35**	-0.30
Agricultural (1 km)	–	–	–	–	–	–	–	–	–	–	1.00	**0.88**	-0.28	**-0.40**	**-0.49**
Agricultural (5 km)	–	–	–	–	–	–	–	–	–	–	–	1.00	-0.22	**-0.38**	**-0.57**
Developed (250 m)	–	–	–	–	–	–	–	–	–	–	–	–	1.00	**0.89**	**0.49**
Developed (1 km)	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	**0.71**
Developed (5 km)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00

Notes:

m = meters, km = kilometers

1 *n* = 47

2 Numbers in table are correlation coefficients (r) between the site attributes, and those with a p value <0.01 are in bold; P values are based on the r value and number of observations (n), and in this analysis values <0.01 are considered to indicate suggestive relationships among variables. Variables were transformed as described in methods prior to calculation of correlation coefficients.

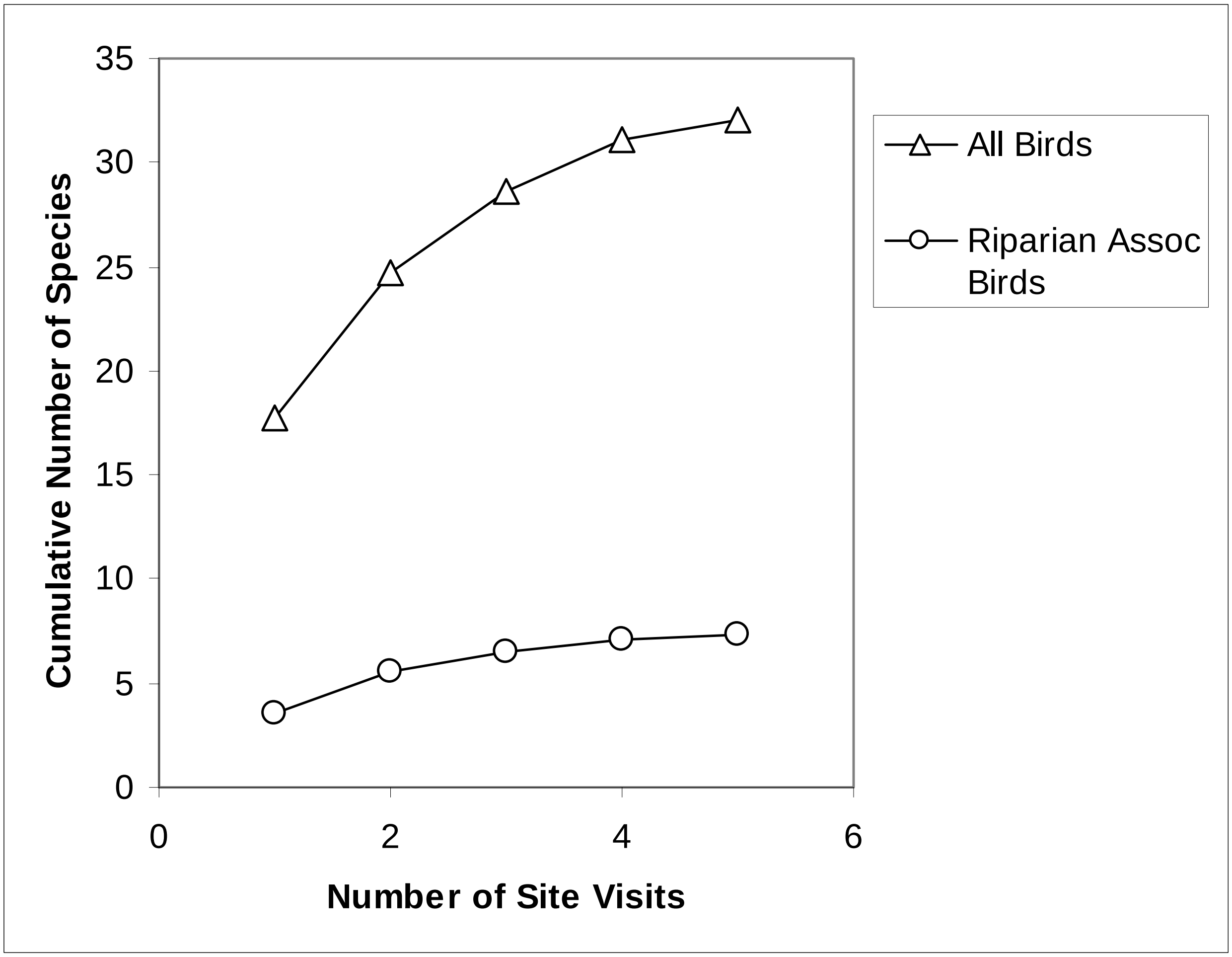


Figure 1. Cumulative Number of Bird Species Observed During Area Searches

Table 6. Summary of Species Observations[1,2]

Species Group	*N*	Mean	SD	Range
Butterfly Spp (2 Surveys)	47	8.6	2.6	4–14
Riparian-Associated Butterfly Spp (2 Surveys)	47	2.4	1.2	0–5
Odonate Spp (1 Survey)	43	7.8	2.3	3–12
Bird Spp (1 Survey)	47	16.3	4.3	6–29
Riparian-Associated Bird Spp (1 Survey)	47	4.3	2.0	0–8
Riparian Associated Bird Spp (4 Surveys)	12	7.4	2.0	4–14
Small Mammal Density (3 nights trapping)[3]	10	12	15	0–39
Mammal Spp (1 Survey)	47	1.5	1.3	0–4
Mammal Spp (4 Surveys)	12	2.3	1.2	1–4
Amphibian and Reptile Spp (1 Survey)	47	0.8	1.0	0–3
Amphibian and Reptile Spp (4 Surveys)	12	2.7	1.1	1–4

Notes:

1 Numbers in table are numbers of species observed per plot, except for small mammal density, which is number of individuals per plot.

2 Abbreviations: N = number of plots, SD = standard deviation, Spp = species.

3 Number of individuals per unit area (not number of species).

With the exception of relationships between surrounding land cover types and vertebrate species richness, our results did not strongly support our initial research hypotheses. In most cases, the species richness of riparian-associated birds was not strongly related to the species richness of other animal groups, though two relationships were significant (Table 7, Figure 2). There was a significant relationship between riparian-associated birds and mammal species (4 surveys, $df = 10$, $r = 0.71$, $p < 0.05$ and < 0.01 without Bonferroni adjustment). There were also significant relationships between potentially resident riparian-associated birds and amphibians and reptiles (based on 4 surveys, $df = 10$, $r = 0.76$, $p < 0.01$, without Bonferroni adjustment $p < 0.005$).

Species richness did not increase significantly with the width of riparian vegetation for any animal group. Correlation coefficients between species groups and riparian width generally were all below 0.40 (Table 8). Results for riparian-associated birds (based on 1 survey) suggested a positive relationship with riparian width ($df = 45$, $r = 0.35$, $p < 0.07$ and < 0.009 without Bonferroni adjustment; Table 8, Figure 3). This could be considered evidence of a significant relationship. However, for the multiple survey plots, there was not a relationship between the number of riparian-associated bird species and riparian width ($df = 10$, $r = 0.16$, $p > 0.25$ without Bonferroni adjustment; Figure 3). Similarly, the species richness of other animal groups had no significant or suggestive positive relationships with riparian width. Riparian width was initially included in four regression models (Table 9), although, in one case (riparian-associated birds based on 1 survey), width was not included in the final model.

In general, species richness of the animal groups had no significant or suggestive relationships with the area of riparian vegetation, and only weak relationships with tree or shrub cover (Table 8). However, riparian-associated birds,, based on 1 survey, had a highly significant relationship with tree cover ($df = 45$, $r = 0.49$, $p < 0.004$ and $p < 0.0005$ without Bonferroni adjustment; Figure 3). The species richness of other animal groups did not have significant or suggestive relationships with riparian woody plant cover.

For the plots receiving multiple surveys, significant correlations existed between vertebrate species richness and surrounding land cover. For these data, nearly half the correlation coefficients were between 0.50 and 0.87, and 14 of these were significant or suggestive (Table 8).

The species richness of riparian-associated birds was significantly related to the extent of surrounding natural and agricultural lands. Riparian-associated birds (based on 4 surveys) had suggestive relationships with percent of surrounding land in natural vegetation within 250 m, 1 km and 5 km ($r = 0.67$–0.73, $p < 0.22$-0.09 and $p < 0.009$–0.004 without Bonferroni adjustment). If the count of riparian-associated bird species at each plot were restricted to just potential nesting species, the relationships to adjacent land cover were stronger. For this set of observed riparian-associated bird species, correlations with agricultural and natural land cover within 250 m had coefficients of -0.84 and 0.82, respectively, indicating strong relationships with surrounding land cover (p values < 0.01-0.02 and < 0.0005 without Bonferroni adjustment). This group also had suggestive relationships to natural and agricultural land cover at other scales (Table 8). Furthermore, no breeding or nesting behaviors were observed for riparian-associated birds at the sites with higher portions of the surrounding area in agricultural land at 250 m (Figure 4).

Similarly, in the multiple survey data sets, the species richness of amphibians, reptiles and mammals was related to surrounding land-cover within 250 m to 5 km. Species richness of amphibians and reptiles had a significant relationship with the portion of the surrounding area in agricultural land for the areas within 1 km and 5 km ($r = -0.78$ and -0.85, respectively, $p < 0.04$ and 0.01, respectively, and p values < 0.002 and < 0.0005 without Bonferroni adjustment). Similarly, species richness of mammals had a significant negative correlation with developed land cover within 250 m and 1 km ($r = -0.82$ and -0.87, respectively, $p < 0.02$ and 0.01, and p values < 0.001 and 0.0005 without Bonferroni adjustment), and suggestive correlations to natural land cover (Table 8).

Although some of the relationships between vertebrate species richness and surrounding land cover were considered just suggestive in the context of this analysis's numerous hypothesis tests, each of these relationships accounted for a moderate portion of the variability among the multiple survey plots in the species richness of a vertebrate group.

Combinations of variables did not produce substantially stronger models for predicting species richness than did single variables. For the individual

Table 7. Correlations Among Species Groups[1,2]

	All Bird Spp	R-A Bird Spp (1 Survey)	R-A Bird Spp (4 Surveys)	R-A, PN Bird Spp (4 Surveys)	Mammal Spp (1 Survey)	Mammal Spp (4 Surveys)	Small Mammal Density	Amphibian & Reptile Spp (1 Survey)	Amphibian & Reptile Spp (4 Surveys)	All Butterfly Spp	R-A Butterfly Spp	Odonate Spp
All Bird Spp (*n* = 47)	1.00	–	–	–	–	–	–	–	–	–	–	–
R-A Bird Spp 1 survey (*n* = 47)	**0.75**[3]	1.00	–	–	–	–	–	–	–	–	–	–
R-A Bird Spp 4 Surveys (*n* = 12)	**0.50**	**0.78**[3]	1.00	–	–	–	–	–	–	–	–	–
R-A, PN Bird Spp 4 Surveys (*n* = 12)	0.53	0.20	0.54	1.00	–	–	–	–	–	–	–	–
Mammal Spp 1 survey (*n* = 47)	0.18	0.06	0.12	0.16	1.00	–	–	–	–	–	–	–
Mammal Spp 4 surveys (*n* = 12)	0.11	0.43	**0.71**[3]	0.32	0.42	1.00	–	–	–	–	–	–
Small Mammal Density (*n* = 10)	0.12	-0.12	0.00	0.58	0.16	0.25	1.00	–	–	–	–	–
Amphibian & Reptile Spp 1 Survey (*n* = 47)	0.32	0.18	0.28	**0.87**[3]	0.29	0.31	-0.13	1.00	–	–	–	–
Amphibian & Reptile Spp 4 Surveys (*n* = 12)	0.20	0.06	0.29	**0.76**[3]	-0.04	-0.13	0.59	**0.62**	1.00	–	–	–
All Butterfly Spp 2 Surveys (*n* = 47)	0.10	0.14	-0.08	-0.06	-0.09	-0.09	-0.26	0.13	-0.02	1.00	–	–
R-A Butterfly Spp 2 Surveys (*n* = 47)	0.14	0.33	-0.30	-0.23	-0.10	-0.15	-0.07	-0.01	0.43	**0.57**	1.00	-
Odonate Spp 1 Survey (*n* = 43)	0.19	-0.01	**0.58**	0.52	-0.24	0.09	-0.07	0.23	0.45	0.04	-0.13	1.00

Notes:

1. Numbers in table are correlation coefficients (*r*) between the number of species observed and the value of a site attribute, and those with a *p* value <0.01 are in bold; *P* values are based on the *r* value and number of observations (*n*), and in this analysis values <0.01 are considered to indicate suggestive or significant relationships among variables. Variables were transformed as described in methods prior to calculation of correlation coefficients.
2. Abbreviations are: R-A = riparian-associated, PN = potentially nesting, and Spp = Species.
3. Correlation significant at ∝ = 0.05 with Bonferroni adjustment.

Table 8. Correlations of Species Observations with Plot Attributes[1]

Species Group[2]	Riparian Width	Tree Cover	Shrub Cover	Riparian (250 m)	Riparian (1 km)	Riparian (5 km)	Natural (250 m)	Natural (1 km)	Natural (5 km)	Agricultural (250 m)	Agricultural (1 km)	Agricultural (5 km)	Developed (250 m)	Developed (1 km)	Developed (5 km)
All Bird Spp (*n* = 47)	0.18	0.27	0.12	-0.05	-0.08	-0.03	0.18	0.15	0.05	-0.03	-0.16	-0.18	-0.22	-0.07	0.13
R-A Bird Spp 1 survey (*n* = 47)	**0.35**	**0.49**[3]	0.18	0.07	0.07	0.16	0.21	0.20	0.20	0.03	-0.10	-0.14	-0.28	-0.16	-0.04
R-A Bird Spp 4 Surveys (*n* = 12)	0.16	0.33	0.04	-0.15	-0.33	-0.40	**0.67**	**0.70**	**0.73**	-0.38	-0.31	-0.23	-0.43	-0.61	-0.50
R-A, PN Bird Spp 4 Surveys (*n* = 12)	-0.01	-0.07	0.34	-0.45	-0.46	-0.52	**0.82**[3]	**0.73**	0.52	**-0.84**[3]	**-0.70**	**-0.67**	-0.15	-0.29	-0.05
Mammal Spp 1 survey (*n* = 47)	0.14	-0.17	0.06	0.32	**0.36**	0.21	0.01	-0.11	-0.10	0.19	0.28	0.27	-0.19	-0.20	-0.21
Mammal Spp 4 surveys (*n* = 12)	0.32	0.33	0.20	-0.12	-0.18	-0.36	**0.70**	**0.76**	0.42	0.05	-0.01	0.12	**-0.82**[3]	**-0.87**[3]	-0.47
Trapped Mammal Density (*n* = 10)	0.39	0.02	0.50	-0.31	-0.37	-0.42	0.62	0.67	0.29	-0.40	-0.47	-0.29	-0.29	-0.30	-0.03
Amphibian & Reptile Spp 1 Survey (*n* = 47)	-0.24	-0.19	-0.17	0.27	0.25	0.30	0.21	0.22	0.28	-0.04	-0.14	-0.25	-0.20	-0.12	-0.04
Amphibian & Reptile Spp 4 Surveys (*n* = 12)	-0.18	-0.19	0.62	-0.44	-0.45	-0.34	0.02	0.35	0.46	-0.46	**-0.78**[3]	**-0.85**[3]	0.37	0.31	0.38
All Butterfly Spp 2 surveys (*n* = 47)	**-0.39**	0.07	-0.11	0.16	0.16	0.05	0.33	0.20	0.25	-0.18	-0.15	-0.29	-0.22	-0.10	0.07
R-A Butterfly Spp 2 surveys (*n* = 47)	0.05	0.30	0.23	0.15	0.18	0.07	0.10	0.13	0.27	-0.06	-0.10	-0.17	-0.08	-0.04	-0.06
Odonate Spp 1 survey (*n* = 43)	-0.24	-0.11	-0.08	-0.19	-0.27	-0.25	0.03	0.04	-0.02	0.11	0.13	0.06	-0.15	-0.26	-0.15

Notes:

1 Numbers in table are correlation coefficients (r) between the number of species observed and the value of a site attribute, and those with a p value <0.01 are in bold; P values are based on the r value and number of observations (n), and in this analysis values <0.01 are considered to indicate suggestive or significant relationships among variables. Variables were transformed as described in methods prior to calculation of correlation coefficients.

2 Abbreviations are: R-A = riparian-associated, PN = potentially nesting, and Spp = Species.

3 Correlation significant at ∝ = 0.05 with Bonferroni adjustment.

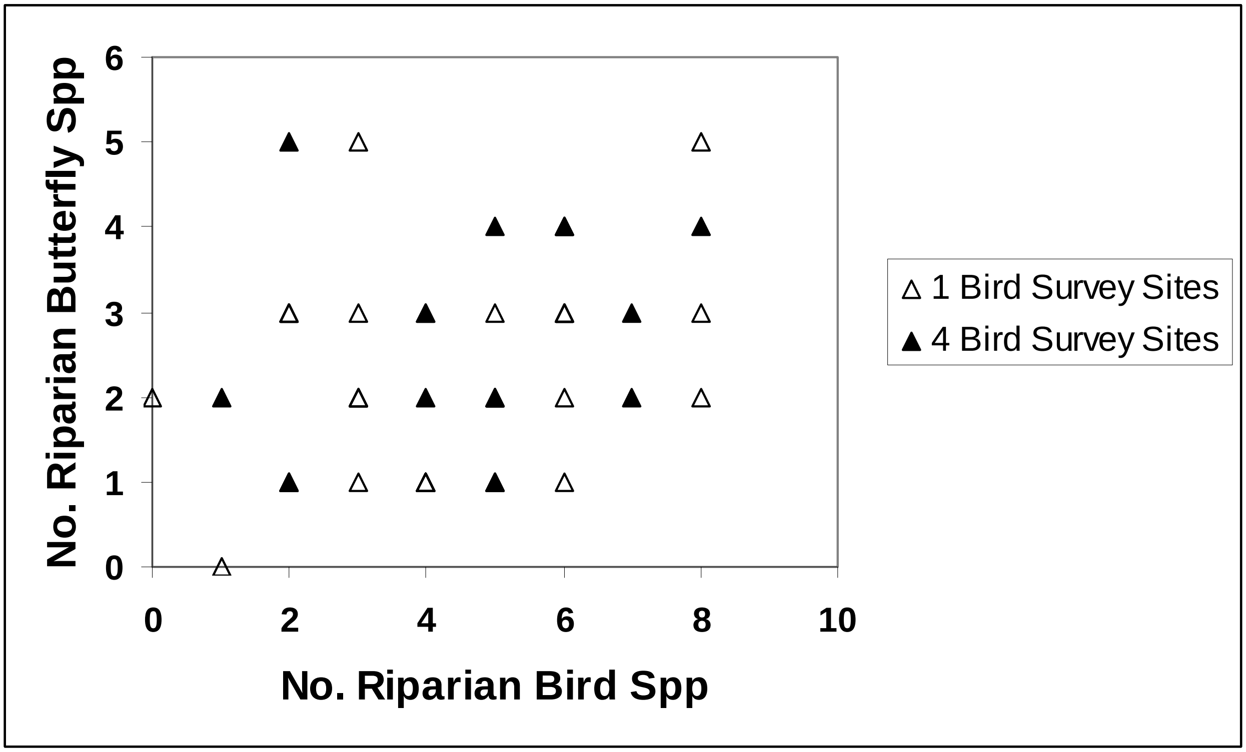
Table 9. Contribution of Variables to Multiple Regression Models for Relationship of Species Groups to Site Attributes[1]

			Sum of Squares (SS) Associated with Variables												
Species Group[2]	R^2	Total SS	Riparian Width	Tree Cover	Shrub Cover	Riparian (1 km)	Riparian (5 km)	Natural (250 m)	Natural (1 km)	Natural (5 km)	Agricultural (250 m)	Agricultural (1 km)	Agricultural (5 km)	Developed (250 m)	Developed (1 km)
All Bird Spp (*n* = 47, p = 0.0426)	0.09	13.59 (100%)	–	1.20 (9%)	–	–	–	–	–	–	–	–	–	–	–
R-A Bird Spp 1 Survey (*n* = 47, p = 0.0003)	0.31	11.63 (100%)	0 (0%)	2.89 (25%)	–	–	–	–	–	–	–	–	–	0.71 (6%)	–
R-A Bird Spp 4 Survey (*n* = 12, p = 0.0115)	0.63	1.53 (100%)	–	–	–	–	–	–	–	0.67 (44%)	–	–	–	–	0.29 (19%)
R-A, PN Bird Spp (*n* = 12, p < 0.0001)	0.90	3.41 (100%)	–	–	–	–	0 (0%)	2.63 (77%)	–	–	0.44 (13%)	–	–	–	–
Mammal Spp 1 Survey (*n* = 47, p = 0.0132)	0.13	9.99 (100%)	–	–	–	1.29 (13%)	–	–	–	–	–	0 (0%)	–	–	–
Mammal Spp 4 Survey (*n* = 12, p = .0175)	0.45	1.37 (100%)	–	–	–	–	–	–	0 (0%)	–	–	–	–	–	0.61 (45%)
Sm. Mammal Density (*n* = 10, p = 0.0641)	0.37	40.16 (100%)	–	–	–	–	–	–	14.68 (37%)	–	–	–	–	–	–
A & R Spp 1 Survey (n = 47, p = 0.0505)	0.13	7.74 (100%)	0.62 (8%)	–	–	–	0 (0%)	–	–	0.36 (5%)	0 (0%)	–	–	–	–
A & R Spp 4 Survey (*n* = 12, p = 0.0017)	0.64	1.01 (100%)	–	–	0 (0%)	–	–	–	–	–	–	–	0.65 (64%)	–	–
All Butterfly Spp (*n* = 47, p = 0.0006)	0.29	8.75 (100%)	1.43 (16%)	–	–	–	–	1.08 (12%)	–	–	–	–	0 (0%)	–	–
R-A Butterfly Spp (*n* = 47, p = 0.0453)	0.09	6.49 (100%)	–	–	–	–	–	–	–	0.56 (9%)	–	–	–	–	–
Odonate Spp (*n* = 43, p = 0.0405)	0.19	7.47 (100%)	0.44 (6%)	–	–	0.44 (6%)	–	–	–	–	–	–	–	–	0.54 (7%)

Notes:

[1] Variables were transformed as described in methods prior to calculation of regression models.

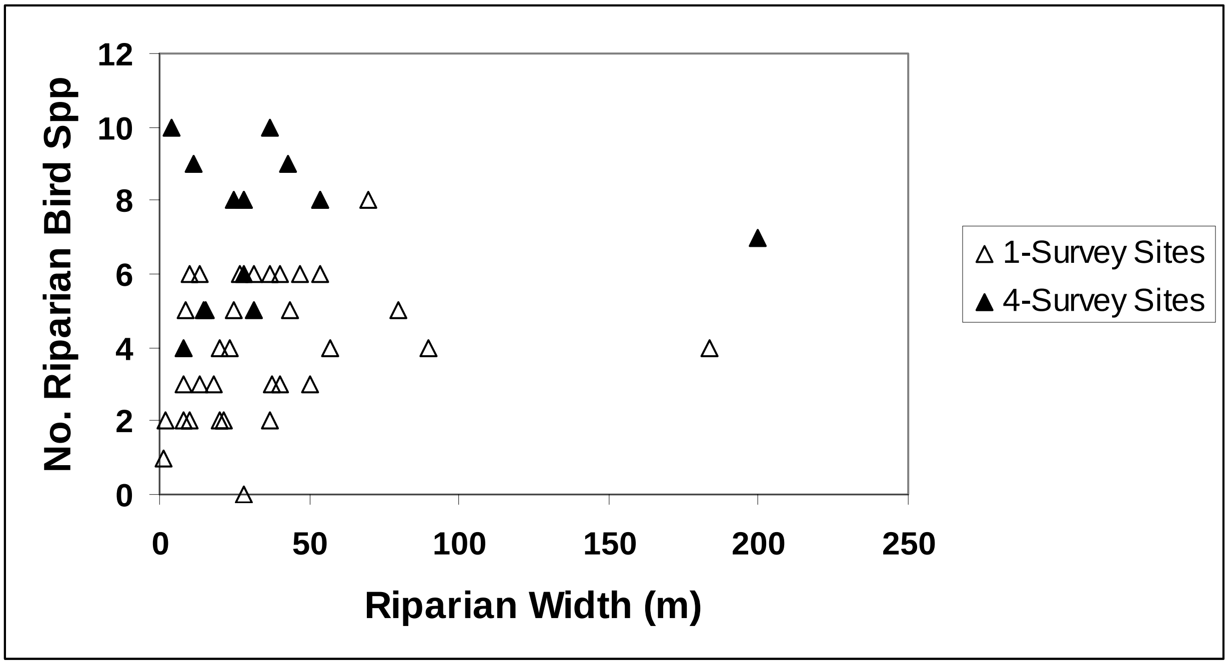
[2] Abbreviations are: R-A = riparian-associated, PN = potentially nesting, A & R = Amphibian and Reptile, and Spp = Species.

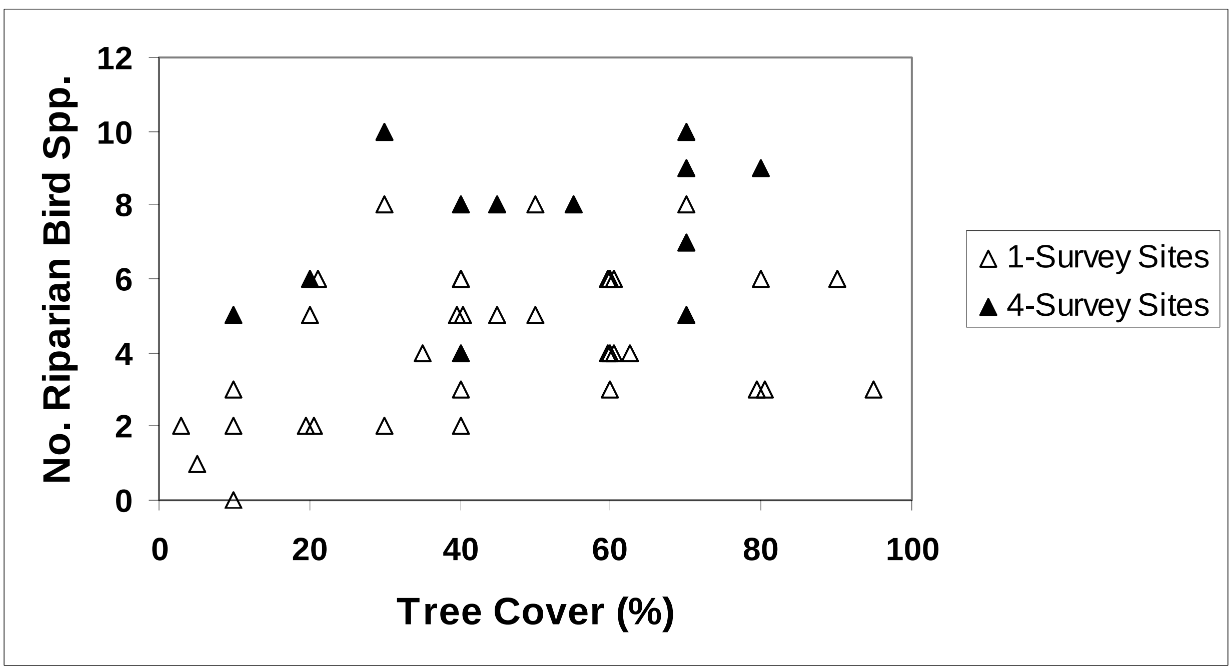


Note:

[1] $n = 47$

Figure 2. Correspondence of Species Richness among Riparian-Associated Birds and Riparian-Associated Butterflies[1]





Note:
[1] n = 47

Figure 3. Relationship of Species Richness of Riparian-Associated Birds and Selected Site Attributes[1]

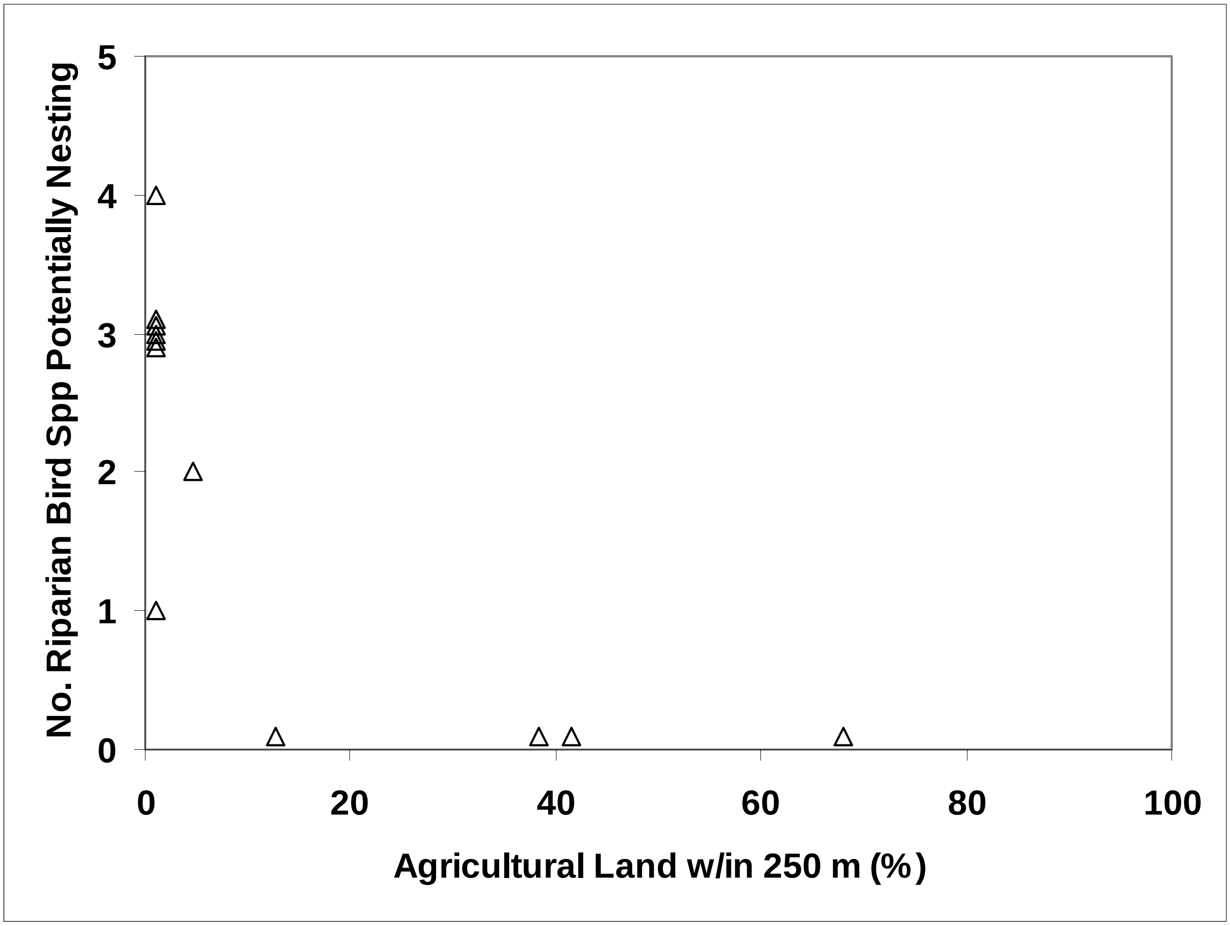


Figure 4. Relationship Between Number of Riparian-Associated Bird Species Potentially Nesting at a Site and Adjacent Agricultural Land

taxonomic groups, simple linear and stepwise multiple regression produced models with p values between < 0.0001 and 0.064 (Table 9). For all vertebrate species, the models consisted of one or two variables and almost all independent variables represented surrounding land cover. Only three of these models had R^2 values > 0.5: riparian-associated birds (4-surveys), riparian-associated birds potentially nesting (4 surveys) and amphibians and reptiles (4 surveys). The amphibian and reptile model was based only on the percent of area within 5 km that was in agricultural land. The model for potential nesting riparian-associated birds was based on two land cover variables, but just one of these (natural vegetation within 250 m) accounted for 86 % of the variability explained by the model. For riparian-associated birds (all observed during 4 surveys regardless of behavior), the regression model based on two variables was substantially stronger than for any one variable ($R^2 = 0.63$).

Discussion

The results of this study must be interpreted cautiously due to limitations of the study's overall sample size, attributes of available sites and chosen methodologies. Nonetheless, the results have implications for assessment methodologies, development of a FAM, and for riparian setbacks. These implications are discussed in the following sections.

Implications for Biological Site Surveys to Assess Riparian Biodiversity

These results indicated that data from multiple site surveys for vertebrates provide a much stronger basis for assessing a riparian area than data from a single site visit. Not only did data from four site surveys document more species than a single survey of those sites, but the results of single and multiple surveys were not highly correlated with each other. Overall, multiple site surveys provide a much more consistent basis for evaluating the habitat value of riparian sites.

These results also indicate that non-destructive area searches for mammals, amphibians, and reptiles were not an effective survey technique, even with the placement of cover boards. Overall, few species were observed during these area searches, usually less than one amphibian or reptile species during a single survey. Though few amphibian or reptile species may have been present, the results still demonstrate that a single non-destructive area search is not an effective means of inventorying the mammal, amphibian, and reptile species using a site. In most plots surveyed multiple times, additional species were observed, indicating that during a single survey most species using a site were not detected. No amphibian or reptiles species was observed beneath any of the 240 cover boards set out and checked 4–6 times during this study. However, cover boards may be more effective is used during late winter-early spring rainy season, when conditions beneath them would be more favorable for amphibians and reptiles, and possibly if constructed using thicker materials that provided better insulation from higher temperatures.

Implications for a FAM

Overall, our results indicate that, for the smaller streams and rivers of the Sacramento Valley, developing a single model that *precisely* quantifies *overall* habitat functions on the basis of readily measured site attributes is not possible, particularly on the basis of available information. However, the results do show that some readily measured site attributes are related to the species richness of particular taxonomic groups. For particular species, guilds, or taxonomic groups, this indicates that useful assessment criteria based on readily measured site attributes could be developed as shown in the examples in Table 10.

In this study, the species richness of different groups (particularly between vertebrates and invertebrates) was not related, and species groups often differed in their relationships to plot attributes. In general, species differ in their biology and thus their habitat requirements, particularly across major taxonomic groups such as vascular plants, butterflies and mammals. Therefore, numerous specific site attributes such as disturbance history, vegetation structure, and presence of host plants, refugia, or rock outcrops affect these species groups differently, and many of these attributes are themselves only loosely related to the landscape variables that are most useful for a cost-effective FAM (e.g., surrounding land use, area and width of riparian vegetation). Thus, models, or assessment criteria, that focus on individual species or guilds will likely provide more useful assessments of a site's habitat value than a model that attempts to quantify habitat value for all species combined (Stein et al. 2000; Smith 2000; Bryce et al. 2002).

In this study, the vertebrate groups had relationships to site attributes, and thus for particular vertebrate taxonomic groups, guilds or species effective assessment criteria based on readily measured site attributes probably could be developed through additional studies. In data from multiple site visits, which were most effective at documenting species' presence, relationships between species richness and surrounding land use were important.

Unfortunately, due to their sample size and the types of data collected, these data sets have substantial limitations. They consist of only twelve plots, and they contain few or no replicates of some important types of sites (e.g., wide riparian corridors in urban areas). They also were scattered over a wide and heterogeneous geographic area. Furthermore, they contain little information on abundance and no information on rates of growth, survival or reproduction. Thus, while these data indicate the importance of surrounding land uses, and other readily measured site attributes, additional studies with larger sample sizes, and collecting other types of ecological data (e.g., density, survival or reproduction), are necessary for defining assessment criteria that precisely quantify habitat values under different combinations of site attributes. We consider such studies important next steps for the conservation planning process.

Table 10. Evaluation of Habitat Functions by Representative Functional Assessment Methods

Assessment	Terrestrial Habitat Functions	Variables used to Assess Habitat Function	Tested[1]
Spatial Wetland Assessment for Management and Planning, SWAMP (Sutter 2001)	Terrestrial wildlife habitat	Area of interior habitat Heterogeneity of vegetation Presence of surface water	No
Assessment of riverine wetlands in Washington State (Hruby et al. 1999)	Bird, Mammal, Amphibian Habitat	Density and condition of snags Presence of special features Evidence of disturbance on adjacent land Interspersion of vegetation types	No
Hydrogeomorphic assessment (HGM) of riverine floodplains in the Northern Rocky Mountains (Hauer et al. 2002)	Characteristic vertebrate habitats	Cover in herb and shrub layers and of native species Tree density Inundation frequency Connectivity of vegetation types	No
Suggested revisions to BLM's Proper Functioning Condition assessment procedure (Stevens et al. 2002)	Fish and wildlife habitat	Canopy connectivity Vegetation patch density Fluvial landform diversity	No
Southern California Riparian Model (Stein et al. 2000)[2]	Condition units[2]	Cover of native plants Percent invasive species Vegetation structural diversity Riparian vegetation continuity Adjacent land cover	No
Bird Integrity Index (Bryce et al. 2002)	Overall riparian integrity including overall habitat integrity	Number or proportion of bird species (or of individuals) in selected guilds	Yes
Tidal freshwater wetlands along Hudson River (Findley et al. 2002)	Breeding Bird, Muskrat and Waterfowl Habitat[3]	Cover or stem density of plant species Soil texture	No[3]
Wetland Assessment, WEA, for San Francisco Bay Region (Breaux and Martindale 2003)	Wildlife Utilization Rating	Guidelines for professional judgment	No
San Diego Creek Assessment (Smith 2000)	Riparian habitat integrity	Native riparian vegetation area Riparian corridor continuity Adjacent land use/land cover	No
Indicator Value Assessment, IVA (Hruby et al. 1995)	General waterfowl, General wildlife	Numerous (>60 indicators)	No
Wetland Habitat Assessment Technique, HAT (Cable et al. 1989)	Habitat quality	Bird species presence Wetland area	No

Notes:

1 Tested by comparison to direct measurements of species presence, abundance or demography. For assessments that used direct measures of animal species group (e.g., birds) presence to assess overall site condition or habitat quality, testing requires comparison to direct measurements of other animal groups.

2 Habitat function incorporated into overall rating (i.e., condition units), and only habitat variables are listed in this table.

3 This study also included fish and aquatic invertebrate habitat functions that were tested by comparison to direct measurements.

As one of these next steps, PRBO's point count dataset provides an excellent opportunity to evaluate relationships between the abundance (i.e., number of individuals) of riparian-associated bird species and riparian width and surrounding land cover. Point count surveys are designed to record the relative abundance of individual species, and PRBO has conducted these surveys for over a thousand locations over multiple years. Their analysis would require the calculation of GIS-based landscape metrics (comparable to the surrounding land cover variables used in this study) and an aerial photo-based interpretation of riparian width. Nonetheless, the analysis of existing PRBO point count data would be a cost-effective means to rigorously analyze relationships between the abundance of species and riparian width and surrounding land cover.

Because of the differences among species groups, and the limitations of current knowledge, a FAM for western Placer County that calculates a single score for a riparian area's habitat functions should be considered only a very general indicator of the overall provision of habitat functions. Such a score should be based on a limited number of variables, preferably just one or two variables that are broadly related to most habitat values and the processes sustaining them (e.g., proportion of surroundings in natural vegetation, hydraulic connectivity). This would limit inaccuracies caused by the operations and coefficients selected to combine variables, and would maintain a mechanistic basis for the assessment.

Implications for Riparian Setbacks

Though width of riparian vegetation was not strongly related to species richness, as measured by these measures, this result should not be interpreted as evidence that the width of a riparian setback is not an important consideration for habitat conservation. This study's sample size, particularly for the multiple survey sites, was small and spread over a large geographic area. Thus, it is likely that only effects of larger magnitude would have been identified and locally important effects would not have been detected without a larger sample size. Width may be important for some species, but these species might be few in number or absent from our data sets. Because all but a few plots represented landscapes substantially altered by human use, most species sensitive to these alterations (including a reduction in riparian width) may no longer be present at any of the study sites. For example, Western Yellow-billed Cuckoo is such a species (Greco et al. 2002) and was not detected at any of the 47 plots during our surveys.

Riparian setbacks would include both riparian and other natural vegetation, and their width would be directly related to the extent of adjacent natural, agricultural and developed land cover; and the proportions of surrounding land-cover types were related to species richness in this study's results. Furthermore, other studies, have shown relationships between the width of riparian vegetation and the presence of riparian-associated animals (Greco et al. 2002).

This study's results indicated that there are important relationships between adjacent land use within 250 m–5 km and the biodiversity of riparian corridors in the Sacramento Valley. These relationships are consistent with studies of riparian habitat elsewhere (Findlay and Houlahan 1996; Forman and Alexander 1998; Bryce et al. 2002; Miller et al. 2003; Semlitsch and Bodie 2003) and with our understanding of factors known to affect riparian species in the Sacramento Valley, such as the availability of upland habitats also used by many of these species. Thus, riparian setbacks should consider both the condition and management of riparian vegetation and the buffer between this vegetation and adjacent developed and agricultural lands. Also, the results suggest that riparian setbacks may not be able to prevent all adverse effects of surrounding land uses on riparian biodiversity, and thus that other conservation measures may be necessary as well. These conservations measures will be discussed in the report providing guidance for riparian setbacks.

However, the results of this study are not by themselves a sufficient basis for recommending setback or buffer widths. For this reason, our report providing guidance for riparian setbacks (Task 5 of the Riparian Ecosystem Assessment), will consider these results together with other available data, and a review of the scientific literature regarding the use of adjacent land by riparian species and the influences of adjacent land uses on those species.

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Appendix A
RAP Forms

Protocol for Description of Riparian Ecosystem Assessment Plots

INTRODUCTION

These protocols provide a guide to assist the survey team in obtaining the required information as efficiently as possible. Minor modifications to these protocols may be necessary depending on access constraints and time available to complete the surveys. All RAP surveys will be done at riparian sites that PRBO has surveyed previously and at Placer County riparian sites where permission is granted from the landowners. Assume that all land is private and do not trespass if you are uncertain about the land ownership. Also, avoid stopping in front of residences and generally be discrete about displaying maps, cameras, and clipboards. Be careful about pulling off roads and do not violate any traffic laws to sample a riparian plot or observe a species. Always leave gates exactly as you found them. Also, for Placer County sites, it is important that all requirements specified by the landowner are followed. These requirements are attached to the directions, map, and photograph for each plot in Placer County.

PREFIELD TASKS

Prior to performing the field surveys, please review the following materials that will be provided in the field packets:

- Road maps and maps of the individual streams showing roads and access points so that survey routes can be planned and surveyed efficiently;
- PRBO field notes giving directions to individual sites, vegetation descriptions, and bird species lists for survey plots;
- Aerial photographs of individual creeks and rivers (as available).

Plan your route to the riparian sites and consult the field checklist to ensure that you have gathered all the necessary equipment to complete the site description and any other RAP survey work you will be conducting (an equipment and contact list is included as Attachment 1).

LOCATING THE PLOT

Proceed to the pre-determined coordinates for the plot center point. Centered on this point, the plot edge ds 100 m along the stream bank edge of the riparian zone (50 m up and 50 m down stream), and then extends 100 m inland (away from the stream bank). In most cases, the actual center of the located plot will differ from the pre-determined coordinates used to locate the plot. Therefore, once the plot boundaries have been determined, the actual coordinates for the plot center point are determined and recorded on the data form (see below).

RIPARIAN RAP DATA FORM

The intent of the RAP data form is to facilitate the collection of field data at selected plots rapidly and accurately. At each plot record the required data in each of the following data fields:

Location

- Provide the River/Creek name and number the plot (e.g., Deer Creek #1).
- Provide the survey date(s) and names of surveyors.
- Use the GPS unit to determine coordinates for the center point of each plot; and record the lat/long on the form. (Elevation will be determined from USGS topographic map and recorded on the form afterwards.)

- Take photographs facing North, East, South, and West, and of a representative view of the riparian corridor. Record their numbers on the form.

Environmental Description

This provides a brief description of the general slope exposure and steepness of the riparian plot that is sampled. If slope varies within the plot, record the slope across the plot as a whole (i.e., from the stream-side to the inland side of the plot).

ADJACENT LAND USES AND IMPACTS

***Developed Non-industrial Land Uses* -** Record the extent of adjacent residential and suburban development with 250 m of the center of the survey plot both by noting the percentage of area covered by these land uses and recording the number of development units (du) observed, including barns and other out buildings.

Agricultural Land Uses – Record agricultural development within 250 m of the center of the plot both by recording the percentage of area covered by agricultural land uses, and by noting the general agricultural type(s) observed.

Industrial Land Uses – Record industrial development within 250 m of the center of the plot both by recording the percentage of area covered by industrial land uses and by noting the general type of industrial uses observed.

Impact Types – In the table provided, for both the riparian and non-riparian portions of the plot, record the presence of the following impacts: brush removal, tree cutting, roadedness, grazing, and trash dumping. The adjacent area extends 250 m from the center of the plot. If the adjacent area is not in natural vegetation, do not record brush cutting, tree cutting, or trash dumping as occurring in the adjacent area. In documenting roadedness, all roads, including dirt and gravel, and other impervious or heavily compacted surfaces are included in this type of impact. For the other category, specify the impact type.

Channel Condition – Indicate whether bank protection has been used in the channel adjacent to the plot, and whether the channel shows evidence of incision. Note whether levees are present at or near the site that may confine the extent of potential riparian habitat areas, and indicate whether there is evidence of overland flow on the plot. Also, indicate the distance to the nearest road (paved, gravel or dirt).

ADDITIONAL COMMENTS

Add any additional comments on site access or interpretation, including management of creeks (e.g., recent revegetation or clearing, channelization, herbicide use, etc.). Also, if aerial photos are available and vegetation has changed since the photograph was taken, this should be noted. Add these additional comments, as necessary, at the bottom of the form.

VEGETATION DESCRIPTION

- In the box provided, enter the Habitat Type(s) using the appropriate Placer County WHR codes (Attachment 2).
- Estimated width of the riparian vegetation. Estimate the width of the riparian stand using a range finder at the center and both ends of each plot and record these widths on the data form.
- Record the surrounding habitat types using the Placer County WHR codes.
- Estimate the total size of the stand from aerial photos and ground inspection, and record its approximate length and continuity, as indicated on the form.
- Record estimates of total absolute cover (expressed as a percentage) of the tree, shrub, and herbaceous layers, and estimate the total extent of unvegetated ground (i.e., bare ground).

- Estimate the total snag density as high (> 20 per hectare), moderate (10-19 ha^{-1}), low (< 10 ha^{-1}), or absent.
- Check the appropriate habitat stage category for that represents the size of the trees dominating the tree layer.
- In the table provided, based on a visual estimate, record the scientific name and check the appropriate category for absolute cover for each woody species in the tree layer (> 3 m), and in the shrub layer (0.5-3 m).

POST-FIELD CHECKLIST

- Check over the field data forms and make sure everything is completed and clear.
- Surveyors should review each other's completed forms for completeness and accuracy in the field.
- From topographic maps, add plot elevations to the RAP data form.
- Photocopy all your field forms. File the copes in the file cabinet in Ted's office and the originals in the Placer Legacy office.
- Download the digital photographs into the P drive folder and rename with the site, point number and orientation (e.g., Thomes 7-1 N, Thomes 7-1 E etc.).
- Download the site coordinates from the GPS into the P drive folder.
- Cross off, date, and initial your completed site on the master list to ensure that field work is not repeated.
- Report progress to the project manager and obtain additional survey packages.

RIPARIAN ECOSYSTEM ASSESSMENT SURVEY PLOTS
RAPID BIOLOGICAL ASSESSMENT FIELD FORM
(J&S--Revised May 7, 2003)

LOCATION

RIVER/CREEK NAME ____ Plot #____________

Surveyors ____**Date** ___________________

Photo #s: ____

GPS Coordinates: Lat. ____°_____'_______" **Long.** _____°_____'_______" **Elevation** (ft/m) ________________
(WGS 84)

ENVIRONMENTAL DESCRIPTION

General Slope Exposure: ___________

General Slope Steepness: 0 degrees_____ 1-5 degrees _____ 5-25 degrees _____ > **25 degrees**

ADJACENT LAND USES AND IMPACTS:

Developed Non-industrial Land Uses ___% of adjacent area**;**
Number of development units per acre: < 1du/ha ___1-2 du/ha _____ > 2 du/ha
Agricultural Land Uses: ___% of adjacent area; Types**:** _____**Orchard** _____ **Vineyard** _____ **Row Crops** ____ **Grain** ___ **Pasture** ___ **Other**
Industrial Land Uses: ___% of adjacent area; Types: ___**Gravel Mining** ____**Other**

Comments ____

Impact Types in Riparian Plot and Adjacent Areas (within 250 m)

IMPACT TYPE	Riparian portion of plot	Non-riparian part of plot	Adjacent Area
Brush removal[1]			
Tree-cutting[1]			
Roadedness[2]			
Grazing[1,3]			
Trash dumping[1]			
Other – specify			

[1] – For adjacent areas not in natural vegetation, do not consider this impact type to be present.
[2] – As roads, include dirt, gravel and paved roads, and other paved surfaces.
[3] – Evidence of grazing includes cows, cow excrement, and tracks.

Bank Protection (e.g. riprap): __% of plot length Channel Incised? Yes No (circle one)

Levee (circle one): [None along stream] [In plot] [Between plot & channel] [Plot between channel & levee]

Evidence of overland flow within plot? Yes No (circle one)

Nearest road : In Plot: Yes No (circle one) If No Road in Plot: Nearest road within ___meters of plot center point.

ADDITIONAL COMMENTS

____

____

____

____

____

VEGETATION DESCRIPTION

Habitat Type (CWHR)	Stand Width (Plot Edge)	Stand Width (Plot Center)	Stand Width (Plot Edge)	Surrounding Habitat Types

Estimated size of total stand: ___< 0.5 ha ___ >0.5-1 ha ___>1-5 ha ___>5-10 ha ___ >10-25 ha ____ >25 ha

Stand Length and Continuity: > 1 km, continuous_____ > 1 km, not continuous _____ 0.5-1 km, continuous _____ 0.5-1 km , not continuous _____ < 0.5 km, continuous ______ <0.5 km, not continuous _____

Total Cover (absolute): Tree Layer: __% Shrub Layer: ___% Herbaceous Layer: __% Bare:___%

Snag Density: High (> 20/ha)_____ **Moderate** (< 20 to 10/ha) _____ **Low** (< 10/ha) _____ **Absent ______**

Predominant Tree Size Class (refer to WHR Habitat Stages for visual examples of each)

Size Class (circle one)	**1**	**2**	**3**	**4**	**5**	**6**
Stage	Seedling	Sapling	Pole	Small	Medium-Large	Multi-storied
DBH	< 1”	1”-6”	6”-11”	11”-24”	>24”	Size 5 over 4 or 3

Woody Plant Absolute Cover in Riparian Portion of Plots

(Check 1 category for each species present)

Species	0-1 %	>1-5 %	>5-25%	>25-50%	>50-75%	>75-95%	>95%
Tree layer (> 3 m)							
Shrub layer (< 3 m)							

Attachment 1. Riparian Assessment Field Equipment

Equipment List

Road maps, area maps, and aerial photographs (as available).
Compass
Clipboard
Rangefinder
Thermometer
Digital Camera
GPS
Cell phone
Fine Sharpies, pencils
J&S equipment bag
Cover boards (if 1st visit to a site where amphibian & reptile data will be collected)

Data Forms

Plot Description Fomr RAP Data Form and Attachments 1, 2, 3
PRBO Area Search Form
Amphibian and Reptile Search Form
Mammal Area Search Form
PRBO Pont Count Form
Small Mammal Trapping data Collection Form
Continuation Pages

Reference Package
RAP Protocols (Plot Description, Area Search and Small Mammal trapping)
Attachment 1. Field Equipment
Attachment 2. CWHR Land Cover and Habitat Types and Codes
Attachment 3. Key to Woody Plants of Central Valley Riparian Zones
Attachment 4. Beaufort Wind Scale
Road map(s)
USGS Quad map

Contacts List

Becky N.	916.752.0973
Ted	530.274.7232
Eric	530.292.0100
Brad	916.752.0923
Margaret	916.752.0941
Kate	916.752.0930
John S.	916.752.0899
Bud	916.752.0938
Jen H.	916.752.0985
Doug	916.835.3197

Placer Wildlife Habitat Relationship Classification
Placer Legacy Phase 1 Area - Land Cover & Habitat Types
2-20-03

Aquatic – Open Water
WL Lacustrine (Lakes/Reservoirs) (generally these features are greater than 1 acre in size)
WR Riverine (Rivers and Creeks) (only mapped if large enough to be mapped accurately on the photographs)

Barren
BR Barren (Cliffs, rock outcrops)
BD Disturbed Lands (Landfills, Graded lands-Non agricultural)

Herbaceous
HA Annual Grassland
HP Pasture - Irrigated
HW Fresh Emergent Wetland
VP Vernal Pool (individual vernal pool >0.5 acre in size) (only mapped if not included in previous mapping and not within a complex)
VC Vernal Pool Complex
- VCh—(High) vernal pool density >7%
- VCm—(Medium) vernal pool density 4-7%
- VCl—(Low) vernal pool density <3%

HS Seasonal Wetland

Shrub
SC Foothill Chaparral

Forested
FR Riparian
FH Foothill Hardwood - includes where signatures are distinguishable:
- FHV Valley Oak Woodland
- FHB Blue Oak Woodland
- FHL Interior Live Oak Woodland

FS Oak Woodland-Savanna (low density oak woodland/savanna mix where density is <= 5 'large' trees per acre)
FOP Oak-Foothill Pine
FP Ponderosa Pine
FE Eucalyptus

Agricultural
AR Rice
AC Row Crops
AA Alfalfa
AP Pasture
AV Vineyards
AO Orchards
AU Unidentified Croplands (including plowed, idle)

Urban

US Urban/Suburban (>1 unit / acre)
UR Rural-residential (0.1 – 1.0 unit / acre) (less than 70% canopy cover of large trees)
  URF Rural-residential Forested (0.1-1.0 unit/acre plus 70-90% canopy cover of large trees)
UP Urban Parks (includes isolated city parks: playgrounds, grass fields, etc)
UG Golf Courses
UT Urban riparian (includes internal riparian areas such as greenbelts, most often surrounded by residential/urban development)
UF Urban woodland (includes city parks with predominate woodland type vegetation and windbreaks with mostly non-native trees)
UW Urban wetland (includes vernal pools, seasonal wetlands, and emergent marshes surrounded by urban uses)

Small-Patch Ecosystems

XW Springs and Seeps
XP Stock Ponds (less than 1 acre)
XL Landscape and Golf Course Ponds (less than 1 acre)

Special Geologic Formations and Soils

XG Gabbrodiorite Soils
XS Serpentine Soils
MR Mehrten Formation Soils

BIRD AREA SEARCH PROTOCOL

INTRODUCTION

These protocols provide a guide to assist the survey team in obtaining the required information as efficiently as possible. Minor modifications to these protocols may be necessary depending on access constraints and time available to complete the surveys. All RAP surveys will be done at riparian sites that PRBO has surveyed previously and at Placer County riparian sites where permission is granted from the landowners. Assume that all land is private and do not trespass if you are uncertain about the land ownership. Also, avoid stopping in front of residences and generally be discrete about displaying maps, cameras, and clipboards. Be careful about pulling off roads and do not violate any traffic laws to sample a riparian plot or observe a species. Always leave gates exactly as you found them. Also, for Placer County sites, it is important that all requirements specified by the landowner are followed. These requirements are attached to the directions, map, and photograph for each plot in Placer County.

PREFIELD TASKS

Prior to performing the field surveys, please review the following materials that will be provided in the field packets:

- Road maps and maps of the individual streams showing roads and access points so that survey routes can be planned and surveyed efficiently;
- PRBO field notes giving directions to individual sites, vegetation descriptions, and bird species lists for survey plots;
- Aerial photographs of individual creeks and rivers (as available).

Plan your route to the riparian sites and consult the field checklist to ensure that you have gathered all the necessary equipment to complete the RAP survey work you will be conducting (an equipment and contact list is included as Attachment 1).

LOCATING THE PLOT

Proceed to the coordinates for the center point of the 100 m by 100 m plot. Centered on this point, the plot edge is 100 m along the stream bank edge of the riparian zone (50 m up and 50 m down stream), and then extends 100 m inland (away from the stream bank).

CONDUCTING THE AREA SEARCH

The area search involves conducting a census of the entire1 ha plot (100 m X 100 m) and recording all bird species detected there. Please use the PRBO area search form to record data. Each area search plot is covered in approximately 1 hour to provide comparable search time at each plot. Typically, at least 3 plots should be covered in a single morning.

Begin the area search by filling out the observer and census information at the top of the PRBO AREA SEARCH FORM. Complete the weather information, and record the air temperature, % cloud cover (% of sky covered in clouds), and approximate wind speed using the attached Beaufort wind scale.

During the census, carefully record the name of each species seen, heard, or for which tracks or scat was observed. Please use the species' common name (not 4-letter codes) to avoid later confusion. For each individual of each species, record a single letter (S=song, V=visual, C=call), in the order of priority explained in the code key. You should change the data (i.e. from a call to a song) if a higher priority observation later occurs for that individual. Also, record breeding and nesting behavior. Recording other special behaviors (such as food carries, flocking, displaying), is strongly recommended but not required; there are respective columns on the form for these observations, following breeding bird atlas methodology. Other species observed off the plot or flying over may be recorded under Notes and Flyovers or on a separate sheet of paper.

In recording species on the data form, note whether the species was observed in the riparian or non-riparian portions of the plot.

POST-FIELD CHECKLIST

- Check over the field data forms and make sure everything is completed and clear.
- Surveyors should review each other's completed forms for completeness and accuracy in the field.
- Photocopy all your field forms. File the copes in the file cabinet in Ted's office and the originals in the Placer Legacy office.
- Cross off, date, and initial your completed site on the master list to ensure that field work is not repeated.
- Report progress to the project manager and obtain additional survey packages.

Beaufort Wind Scale

Used to guage wind speed using observations of the winds effects on trees and other objects. Often used in monitoring projects because it doesn't require fancy equipment.

Format: Beaufort Number * Wind Speed in Miles/hour(Km/hour) *** Description**

0 *** <1 (<1.6)*****Calm:** Still: Smoke will rise vertically.

1***1-3(1.6-4.8)*** **Light Air:** Rising smoke drifts, weather vane is inactive.

2***4-7(6.4-11.3)*****Light Breeze:** Leaves rustle, can feel wind on your face, weather vane is inactive.

3***8-12(12.9-19.3)*****Gentle Breeze:** Leaves and twigs move around. Light weight flags extend.

4***13-18 (20.9-29.0)*****Moderate Breeze:** Moves thin branches, raises dust and paper.

5***19-24 (30.6-38.6)*****Fresh Breeze:** Moves trees sway.

6***25-31(40.2-50.0) *****Strong Breeze:** Large tree branches move, open wires (such as telegraph wires) begin to "whistle", umbrellas are difficult to keep under control.

7***32-38 (51.5-61.2)*****Moderate Gale:** Large trees begin to sway, noticeably difficult to walk.

8***39-46(62.8-74.0)*****Fresh Gale:** Twigs and small branches are broken from trees, walking into the wind is very difficult.

9***47-54(75.6-86.9)*****Strong Gale:** Slight damage occurs to buildings, shingles are blown off of roofs.

10***55-63 (88.5-101.4)*****Whole Gale:** Large trees are uprooted, building damage is considerable.

11***64-72 (103.0-115.9)*****Storm:** Extensive widespread damage. These typically occur only at sea, and rarely inland.

12***>73 (>115.9)*****Hurricane:** Extreme destruction.

NOTE: The Beaufort number is also referred to as a "Force" number, for example,
"Force 10 Gale".

* To calculate knots, divide miles/hour by 1.15.

PRBO AREA SEARCH FORM

Observer Information	Census Information
Observers	River/Creek Plot #
Date	Location (County)

__________°F or °C (circle one) Temperature   _________% Cloud Cover   _________ mph , knots, or kmph (circle one) Wind Speed

Number of Observers: ______ **Start Time:** _______________ **End Time:** _____________

Species	**Tally of Individuals** (Song, Visual, Call, one letter per individual)	**Total**	**Behavior** (check if applicable)*								
								carry			
			Forage.	Flock	Copul.	Displ.	Pair	Mater.	Food	Nest	Fledge.

*Forag. = foraging, Copl. = copulation, Displ. = courtship or territorial display, Food carry includes fecal sack, Fledg. = fledgling.

Notes and flyovers:____

____

____

____

____

PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970
415-868-1221
www.prbo.org

prbo

Be sure you have the following:

- binoculars
- watch which indicates seconds
- at least 2 pens
- field notebook
- sufficient blank data forms
- clipboard
- rubber bands (for holding forms on clipboard)

Depending on the route, census type, and your experience level, you may also need:

- directions and maps
- GPS unit & extra batteries
- cell phone or radio
- range finder
- field guide
- water and snacks

Counts begin approximately 15 minutes after local sunrise and should be completed within 3-4 hours, generally by 10AM.

We recommend 2-3 visits per season (e.g., twice in May and once in June). Visits should be at least 10-15 days apart. Timing of the field season will vary by location, but should cover the local breeding season with as little overlap with migration or dispersal as possible.

When possible, the order in which points are surveyed should vary between visits. Ideally, observers should also vary among visits.

Do not conduct surveys during weather conditions that likely reduce detectability (e.g., high winds or rain). If conditions change for the worse while doing a count, remaining points can be completed <7 days from the first day, but this should be avoided as much as possible.

Approach the point with as little disturbance to the birds as possible, and begin your count as soon as you are oriented and are confident you can estimate distances accurately (less than 1 minute).

PRBO point counts are 5 minutes duration at each point. Record the time the survey begins at each point using the 24-hour clock. If something interferes with your ability to detect birds during the 5-minute count, stop the count until the disturbance has passed and start over. Cross out the interrupted data and note what happened on your form.

Every species detected at a point is recorded, regardless of how far from the observer. Use the standardized banding lab 4-letter abbreviation for species codes (http://www.pwrc.usgs.gov/bbl/manual/bandsize.htm) and follow the naming conventions maintained by the American Ornithologists Union (http://www.aou.org/aou/birdlist.html). For unknown species, record "XXXX." For unknown members of various families, use "XX" plus two letters to signify the family – "XXHU" for unidentified hummingbird, for example. You can follow birds after the completion of a point in order to verify identification. If no birds are detected at a point, write "No birds detected" on your form. We recommend keeping a list of all species detected between points (i.e., not during the 5 minute counts) on the back of your form.

For each individual detected we record the distance to the detection and the behavior that alerted us to the individuals' presence. Also, for each species we record any indications of breeding status. Make every effort to avoid double counting individuals detected at a single point. However, if an individual is known or thought to have been counted at a previous point, make a note of it, but record its presence at the current point anyway. No attracting devices, recordings, or "pishing" should be used.

Distance: All point counts involve recording distance to detections at some level of resolution. Depending on project, we use either 50m fixed-radius counts, or Variable Circular Plots (VCP), in which the distance to each detection is recorded to the nearest 10m (though this distance may vary by project and habitat type – consult project leader). Both methods also specify whether or not detections were beyond 100m.

Note: Fifty m radius counts may not provide sufficient data for calculating population density or trends for some species or habitats where the use of VCP's may improve estimates. We recommend the use of range finders and extensive training for either method, but especially for VCP. VCP data should always be taken in a way that is transferable to 50m format.

The distance recorded is the distance from the point to the first location an individual was observed, regardless of its behavior. If the bird subsequently moves, *do not change the original distance recorded*. If a bird is flying (but not "flying over" – see below), or perched high in a tree, the distance recorded is to the point at which a plumb line would hit the ground if hung from the point at which the bird was first observed. This distance should be measured as though a tape were laid across the ground, that is, including any intervening topographic features.

A bird flushed from within 10m of the point when you arrive should be included in the count. Birds that are flushed from farther away should be noted on the back of the form if they are species that didn't occur during the count.

We record the behavioral cue that alerted us to the presence of the individual - generally "S" for song, "V" for visual, or "C" for call ("D" for drumming woodpecker, "H" for humming hummingbird). If a bird sings after it has been detected via a different cue, this is indicated in the data, but the initial detection cue is preserved. Circle the original detection cue ("V" or "C") to note that a bird was singing subsequent to its initial detection, but otherwise, no changes in behavior are noted. Juvenile birds are recorded as "J"s regardless of their behavior, and are not included in most analyses.

Birds that are flying over but not using the habitat on the study area are recorded in the fly-over column. Birds flying below canopy level, flying from one perch to another, or actively foraging on or above the study area are recorded as described in the previous paragraphs.

Breeding status: We record any potential indications of breeding if noted for species at each point as follows:

- CO – copulation
- DI – territorial display.
- DD – distraction display
- FC – food carry
- FL – fledglings
- FS – fecal sac carry
- MC – material carry
- NF – nest found
- PA – pair

Riparian Ecosystem Assessment Mammal Area Search Protocol

INTRODUCTION

These protocols provide a guide to assist the survey team in obtaining the required information as efficiently as possible. Minor modifications to these protocols may be necessary depending on access constraints and time available to complete the surveys. All RAP surveys will be done at riparian sites that PRBO has surveyed previously and at Placer County riparian sites where permission is granted from the landowners. Assume that all land is private and do not trespass if you are uncertain about the land ownership. Also, avoid stopping in front of residences and generally be discrete about displaying maps, cameras, and clipboards. Be careful about pulling off roads and do not violate any traffic laws to sample a riparian plot or observe a species. Always leave gates exactly as you found them. Also, for Placer County sites, it is important that all requirements specified by the landowner are followed. These requirements are attached to the directions, map, and photograph for each plot in Placer County.

PREFIELD TASKS

Prior to performing the field surveys, please review the following materials that will be provided in the field packets:

- Road maps and maps of the individual streams showing roads and access points so that survey routes can be planned and surveyed efficiently;
- PRBO field notes giving directions to individual sites, vegetation descriptions, and bird species lists for survey plots;
- Aerial photographs of individual creeks and rivers (as available).

Plan your route to the riparian sites and consult the field checklist to ensure that you have gathered all the necessary equipment to complete the RAP survey work you will be conducting (an equipment and contact list is included as Attachment 1).

LOCATING THE PLOT

Proceed to the coordinates for the center point of the 100 m by 100 m plot. Centered on this point, the plot edge is 100 m along the stream bank edge of the riparian zone (50 m up and 50 m down stream), and then extends 100 m inland (away from the stream bank).

SEARCHING FOR MAMMALS

Area searches are conducted for approximately 1 hour to ensure comparable search effort on each plot. Begin the area search by entering the observer, date, time and site information at the top of the *Mammal Area Search* form. During the census, carefully record the name of each species seen or heard. Please use the species' common name (not 4-letter codes) to avoid later confusion. The area search involves walking throughout the entire (100 m by 100 m) plot.

POST-FIELD CHECKLIST

- Check over the field data forms and make sure everything is completed and clear.
- Surveyors should review each other's completed forms for completeness and accuracy in the field.

- Photocopy all your field forms. File the copes in the file cabinet in Ted's office and the originals in the Placer Legacy office.
- Cross off, date, and initial your completed site on the master list to ensure that field work is not repeated.
- Report progress to the project manager and obtain additional survey packages.

Mammal Area Search Form

Site: ______________________________________ **Plot**: ______________

Date: ______________ **Start Time**: _______ **Stop Time**: _____

Observer: ________________________________

Temperature: ________ **Cloud Cover**: _________

Species	Visual Observation	Vocalization	Scat	Tracks	Prey Remains	Notes

Additional Comments:

Riparian Ecosystem Assessment Amphibian & Reptile Search Protocol

INTRODUCTION

These protocols provide a guide to assist the survey team in obtaining the required information as efficiently as possible. Minor modifications to these protocols may be necessary depending on access constraints and time available to complete the surveys. All RAP surveys will be done at riparian sites that PRBO has surveyed previously and at Placer County riparian sites where permission is granted from the landowners. Assume that all land is private and do not trespass if you are uncertain about the land ownership. Also, avoid stopping in front of residences and generally be discrete about displaying maps, cameras, and clipboards. Be careful about pulling off roads and do not violate any traffic laws to sample a riparian plot or observe a species. Always leave gates exactly as you found them. Also, for Placer County sites, it is important that all requirements specified by the landowner are followed. These requirements are attached to the directions, map, and photograph for each plot in Placer County.

PREFIELD TASKS

Prior to performing the field surveys, please review the following materials that will be provided in the field packets:

- Road maps and maps of the individual streams showing roads and access points so that survey routes can be planned and surveyed efficiently;
- PRBO field notes giving directions to individual sites, vegetation descriptions, and bird species lists for survey plots;
- Aerial photographs of individual creeks and rivers (as available).

Plan your route to the riparian sites and consult the field checklist to ensure that you have gathered all the necessary equipment to complete the RAP survey work you will be conducting (an equipment and contact list is included as Attachment 1).

Where data on amphibians and reptiles will be collected, cover boards will be placed out during the first visit to the site, and will be checked during the next visit (at least a week later).

LOCATING COVER BOARDS WITHIN THE PLOT

Proceed to the coordinates for the center point of the 100 m by 100 m plot. Centered on this point, the plot edge is 100 m along the stream bank edge of the riparian zone (50 m up and 50 m down stream), and then extends 100 m inland (away from the stream bank). Locate the first 100 m line of cover boards along the length of the stream bank side of the plot. Place 10 cover boards, evenly spaced apart, along this first line. Place an additional 10 cover boards along a second 100 m line 10 m in from the stream bank side of the plot and parallel to the first line of cover boards.

SEARCHING FOR AMPHIBIANS AND REPTILES

Area searches are conducted for approximately 1 hour to ensure comparable search effort on each plot. (If area searches deviate from the 1 hour duration, note this in the “Additional Comments” section of the data form.) Begin the area search by entering the observer, date, time and site information at the top of the *Amphibian and Reptile Data Collection* form. During the census, carefully record the name of each species seen or heard. Please use the species' common name (not 4-letter codes) to avoid later confusion. The area search involves walking throughout the entire (100 m by 100 m) plot and also checking under all cover boards. In checking cover boards, quickly lift each cover board and identify species present. Only handle amphibians and reptiles if you have a DFG permit and you cannot identify them. Most species should be identifiable without handling them. After it has been checked, replace each board in its original position. Please collect all cover boards and remove any flagging after the final plot survey.

POST-FIELD CHECKLIST

- Check over the field data forms and make sure everything is completed and clear.
- Surveyors should review each other's completed forms for completeness and accuracy in the field.
- Photocopy all your field forms. File the copes in the file cabinet in Ted's office and the originals in the Placer Legacy office.
- Cross off, date, and initial your completed site on the master list to ensure that field work is not repeated.
- Report progress to the project manager and obtain additional survey packages.

Amphibian and Reptile Data Collection Form

Site: ______________________________________ **Plot**: ______________

Date: ______________ **Start Time**: _______ **Stop Time:** _____

Observer: _________________________

Temperature: ________ **Cloud Cover**: _________

Species	Visual Observation	Vocalization	Under Cover	Notes

Additional Comments:

Riparian Ecosystem Assessment Butterfly Search Protocol

INTRODUCTION

These protocols provide a guide to assist the survey team in obtaining the required information as efficiently as possible. Minor modifications to these protocols may be necessary depending on access constraints and time available to complete the surveys. All RAP surveys will be done at riparian sites that PRBO has surveyed previously and at Placer County riparian sites where permission is granted from the landowners. Assume that all land is private and do not trespass if you are uncertain about the land ownership. Also, avoid stopping in front of residences and generally be discrete about displaying maps, cameras, and clipboards. Be careful about pulling off roads and do not violate any traffic laws to sample a riparian plot or observe a species. Always leave gates exactly as you found them. Also, for Placer County sites, it is important that all requirements specified by the landowner are followed. These requirements are attached to the directions, map, and photograph for each plot in Placer County.

PREFIELD TASKS

Prior to performing the field surveys, please review the following materials that will be provided in the field packets:

- Road maps and maps of the individual streams showing roads and access points so that survey routes can be planned and surveyed efficiently;
- PRBO field notes giving directions to individual sites, vegetation descriptions, and bird species lists for survey plots;
- Aerial photographs of individual creeks and rivers (as available).

Plan your route to the riparian sites and consult the field checklist to ensure that you have gathered all the necessary equipment to complete the RAP survey work you will be conducting (an equipment and contact list is included as Attachment 1).

Where data on amphibians and reptiles will be collected, cover boards will be placed out during the first visit to the site, and will be checked during the next visit (at least a week later).

SEARCHING FOR BUTERFLIES

All butterfly area searches must take place between 9 AM and 4 PM because of the daily flight patterns of butterflies. Area searches are conducted for approximately 1 hour to ensure comparable search effort on each plot. (If area searches deviate from the 1 hour duration, note why in the “Additional Comments” section of the data form.) Begin the area search by entering the observer and site information at the top of the *Butterfly Area Search* form. The area search involves walking throughout the entire (100 m by 100 m) plot. During the census, carefully record the name of each species seen. Please use the species’ scientific name (not 4-letter codes) to avoid later confusion. Indicate the relative abundance of each species in the *General Abundance* column of the data form using the following scale: Rare (1 individual), Uncommon (2-5 individuals), Common (5-10 individuals), Abundant (> 10 individuals).

POST-FIELD CHECKLIST

- Check over the field data forms and make sure everything is completed and clear.

- Surveyors should review each other's completed forms for completeness and accuracy in the field.
- Photocopy all your field forms. File the copes in the file cabinet in Ted's office and the originals in the Placer Legacy office.
- Cross off, date, and initial your completed site on the master list to ensure that field work is not repeated.
- Report progress to the project manager and obtain additional survey packages.

Area Search for Butterfly Species

Site: ________________________________ **Plot**: ____________

Date: ____________ **Start Time**: ______ **Stop Time**: ____

Observer: _____________________

Notes on Weather: ____

____

Species	In Riparian	Out of Riparian	General Abundance	Notes

Additional Comments:

Riparian Ecosystem Assessment Small Mammal Trapping Protocol

INTRODUCTION

These protocols provide a guide to assist the survey team in obtaining the required information as efficiently as possible. Minor modifications to these protocols may be necessary depending on access constraints and time available to complete the surveys. All RAP surveys will be done at riparian sites that PRBO has surveyed previously and at Placer County riparian sites where permission is granted from the landowners. Assume that all land is private and do not trespass if you are uncertain about the land ownership. Also, avoid stopping in front of residences and generally be discrete about displaying maps, cameras, and clipboards. Be careful about pulling off roads and do not violate any traffic laws to sample a riparian plot or observe a species. Always leave gates exactly as you found them. Also, for Placer County sites, it is important that all requirements specified by the landowner are followed. These requirements are attached to the directions, map, and photograph for each plot in Placer County.

PREFIELD TASKS

Prior to performing the field surveys, please review the following materials that will be provided in the field packets:

- Road maps and maps of the individual streams showing roads and access points so that survey routes can be planned and surveyed efficiently;
- PRBO field notes giving directions to individual sites, vegetation descriptions, and bird species lists for survey plots;
- Aerial photographs of individual creeks and rivers (as available).

Plan your route to the riparian sites and consult the field checklist to ensure that you have gathered all the necessary equipment to complete the RAP survey work you will be conducting (an equipment and contact list is included as Attachment 1).

LOCATING TRAPS WITHIN THE PLOT

Proceed to the coordinates for the center point of the 100 m by 100 m plot. Centered on this point, the plot edge is 100 m along the stream bank edge of the riparian zone (50 m up and 50 m down stream), and then extends 100 m inland (away from the stream bank). Locate the first 100 m line of traps along the length of the stream bank side of the plot. Place 15 traps, evenly spaced apart, along this first line. Place an additional 15 traps along a second 100 m line 10 m in from the stream bank side of the plot and parallel to the first line of traps.

CONDUCTING THE SMALL MAMMAL TRAPPING

Trapping will be conducted for three consecutive nights at each plot All traps will be set within 2 hours of sunset and checked within 3 hours after sunrise the following morning. Each trap will be baited with peanut butter and rolled oats, and a wad of cotton was placed at the back of each trap for bedding.

Each animal captured will be identified to species, and its age, sex, reproductive condition, and general health will be evaluated and noted. The time, location of capture, and general weather and habitat conditions also will be recorded. Photographs will be taken of each study plot and each new species captured. All data will be recorded on standardized Jones & Stokes field forms

(Attached). Each captured animal will be marked with a permanent nontoxic felt pen so it could be identified as a recapture if trapped on subsequent trap-nights. All animals will be released at the site of capture.

All Jones & Stokes biologists conducting the small mammal surveys will wear appropriate protective clothing and respirators during the handling of the animals to avoid potential exposure to Hantivirus. Standard precautionary measures identified in Mills et al. (1995) *Guidelines for Working with Rodents Potentially Infected with Hantivirus* will be observed during this work.

Once tapping has been completed all traps and flagging will be removed from the site.

POST-FIELD CHECKLIST

- Check over the field data forms and make sure everything is completed and clear.
- Surveyors should review each other's completed forms for completeness and accuracy in the field.
- Photocopy all your field forms. File the copes in the file cabinet in Ted's office and the originals in the Placer Legacy office.
- Cross off, date, and initial your completed site on the master list to ensure that field work is not repeated.
- Report progress to the project manager and obtain additional survey packages.

Project: Placer Riparian Ecosystem Assessment

Site:________________ **Plot:** ____________

Date:_____/_____/03 **Start Survey Time:**___________ **End Survey Time:**___________

Team Members: ____

____

Weather: Temp:______F; **Wind:** _______mph from_______; **Clouds:** __________; **Precip:**________

Other Site Conditions: ____

____

Photos: ____

Trap Survey Results

Time	Site	Location	Cl	Species	Sex	Age	Condition	Recapture?	Marked?	

Trap check-off

Trap #	Trap Line		
	1	2	3
1			
2			
3			
4			
5			
6			
7			
7			
8			
10			
11			
12			
13			
14			
15			
Enter species code for each capture.			
If trap is empty, put "x" in box			

Notes:

Project Manager sign-off:

Draft 19 May, 2003

A KEY TO THE WOODY PLANTS OF RIPARIAN ZONES IN CALIFORNIA"S CENTRAL VALLEY

By John C. Hunter, Jones & Stokes, 2600 V Street, Sacramento CA 95818 jhunter@jsanet.com

1. Plant a large (up to several m high), densely clumped grass, with thick (> 2 cm) woody stems … *Arundo donax* (Giant reed)
1. Plant not a grass … 2
    2. Leaves compound (the thin flat portion of the leaf discontinuous) … 3
        3. Leaves opposite (> 1 leaf attached to stem in same plane) … 4
            4. Leaflets palmately arranged (radiating from a central point), flowers > 1 cm long, fruit with a husk that separates from the large (> 3 cm in diameter) round seed … *Aesculus californica* (California buckeye)
            4. Leaflets pinnately arranged (feather-like, arranged like ribs off a backbone), flowers < 1 cm long and fruits either flat and winged or small (<5 mm across) round and fleshy … 5
                5. Fruits dry and winged (with a thin flat extension), flowers inconspicuous, pith (in center of stem) not particularly large … 6
                    6. Fruit two-parted, each part with a wing; Leaves with 3-7 leaflets; Leaflet margins coarsely toothed … *Acer negundo* (box elder)
                    6. Fruit one-parted with one wing; Leaves with 5-7 leaflets; Leaflet margins smooth or with fine (small) teeth … *Fraxinus latifolia* (Oregon ash)
                5. Fruits fleshy without a wing, pith conspicuously large and spongy, flowers small and white (or cream) but showy in a dense inflorescence (cluster) … 7
                    7. Flowers in a broad flat clusters, Fruits black (sometimes white) with a white waxy coating that causes them to appear blue … *Sambucus mexicana* (Blue elderberry)
                    7. Flowers in rounded to cylindrical clusters, Fruits red, or black, without a waxy covering … *Sambucus racemosa* (Red elderberry)
        3. Leaves alternate (just 1 leaf attached to stem at any perpendicular plane) … 8
            8. Plant a legume (Our woody species in the Central Valley have pea-like flowers in drooping clusters, fruit a dry pod with multiple seeds) … 9
                9. A tree with white flowers, spines at the base of leaves, and a flat pod … *Robinia pseudoacacia* (black locust)
                9. A shrub or small tree with red flowers, no spines, and a pod with four "wings" … *Sesbania punecia*
            8. Plant not a legume … 10
                10. Plant w/ prickles … 11
                    11. Fruits dry, enclosed in a fruit-like fleshy to leathery sac (a rose hip); Leaflets pinnately arranged (feather-like, arranged like ribs off a backbone) … *Rosa californica* (California rose)
                    11. Fruits fleshy, blackberry-like; Leaflets palmately arranged (radiating from a central point) … 12
                        12. Leaves white on underside; Prickles broad-based; Stems often stout and ribbed (ridged); Leaflets 3-5; Flowers/fruits > 10 in each inflorescence (cluster) … *Rubus procerus* (Himilayan blackberry)
                        12. Leaves light green on underside; Prickles slender; Stems round; Leaflets 3; Flowers/fruits 2-15 in an inflorescence … *Rubus ursinus* (California blackberry)
                10. Plant w/o prickles … 13
                    13. Leaflets with a round gland (a thickened dot) near the base, fruit flat, dry with a wing … Ailanthus (Tree-of-Heaven)
                    13. Leaflets without a basal gland, fruit round, fleshy or leathery and without a wing … 14
                        14. Plant a vine or shrub; Leaflets 3-5; Leaflet margins lobed, coarsely toothed or smooth; Fruits small (< 1 cm) … *Toxicodendron diversilobum* (Poison oak)
                        14. Plant a tree, Leaflets 11-19; Leaflet margins sharply toothed but not lobed; Fruits large (> 2.5 cm across) … *Juglans californica* var. *hindsii* (Northern California black walnut)

2. Leaves simple (the thin flat portion of the leaf continuous)
   - 15. Plant a willow: Fruit a capsule with seeds embedded in cottony fluff; Leaves alternate, deciduous and narrow (ranging from linear (almost not taper) to lance-shaped); Buds covered by a single scale; Bark bitter tasting and astringent with an aspirin-like flavor … 16
     - 16. Scale covering bud in axil of leaf (where leaf meets stem) has free and overlapping margins (you can see this by pressing down on the tip of the bud and rocking it from side to side); Axillary bud small (< 3 mm), conical and pointed … 17
       - 17. Leaf dull green on both sides; stipules (a pair of small leafy or dry and papery bracts where the leaf joins the stem) absent; Twigs of the current year tend to be yellow to olive, Plant a tree to 30 m high … *Salix gooddingii* (Gooding's black willow)
       - 17. Leaf glossy green above and glaucous (waxy white) below; stipules generally present; Current year twigs typically red to yellowish brown; Plant a tree to 14 m … *Salix laevigata* (Red willow)
     - 16. Scale covering bud in axil has margins fused together so that the scale forms a cap; Axillary bud small to large, with a rounded tip and shape elliptic to conical … 18
       - 18. Leaves narrow (linear and generally < 1 cm wide) with upper and lower surfaces similar, both covered (thickly or thinly) in silky hairs; Plant a clonal, multi-stemmed shrub to 6 m … *Salix exigua* (Sandbar or Narrow leaf willow)
       - 18. Leaves broader (elliptic to lance-shaped and generally > 1 cm wide) with upper surfaces shiny green and lower surfaces pale green or glaucous (waxy white), hairs generally restricted to young leaves; Plant a shrub or small tree to 18 m … 19
         - 19. Petiole (stalk of leaf) with glands at base of blade (these glands appear as small warty, irregular protrusions); Leaves 5-17 cm long, lance-shaped and gradually tapering towards the tip with concave sides (long acuminate)… *Salix lucida* var. *lasiandra*, (Shining willow)
         - 19. Petiole without glands; Leaves 3-12 cm long, narrowly lance-shaped to elliptic, tapers to tip with convex sides … *Salix lasiolepi*s, (Arroyo willow)
   - 15. Plant not a willow and the complete set of attributes not as above; Fremont's cottonwood is in the willow family and shares some of the traits described above except that its leaves are broad and triangular to heart-shaped and its buds have > 1 scale; For other species: Fruit not a capsule and seeds not embedded in cottony fluff; Leaves alternate or opposite, deciduous or evergreen and narrow or broad; Buds covered by more than one scale; Bark taste varied but without an aspirin-like flavor;
     - 20. Plant an oak: Fruit an acorn; Buds clustered near the branch tips; Plant a tree … 21
       - 21. Leaves with bristles *Quercus wislizenii* (Interior live oak) – However, at higher elevations, if underside of leaf has a pale bluish cast and it covered in powdery dust, the plant could be could be *Quercus chrysolepis* (Canyon live oak)
       - 21. Leaves w/o bristles … 22
         - 22. Leaves deeply lobed (often > ½ distance to midrib); Acorn 3-5 cm long; Leaves upper surface with a greenish cast … *Quercus lobata* (Valley oak)
         - 22. Leaves shallowly lobed (< ½ distance to midrib) or wavy margined; Acorn 2-3.5 cm long; Leaves upper surface often with a bluish cast … *Quercus douglasii* (Blue oak)
     - 20. Plant not an oak: Fruit not an acorn; Buds generally not clustered near branch tips; Plant a tree, shrub or vine … 23
       - 23. Plant a woody vine … 24
         - 24. Plant evergreen, lacking tendrils … *Hedera helix* (Ivy)
         - 24. Plant deciduous and with tendrils opposite leaves … *Vitis californica* (California wild grape)
       - 23. Plant a shrub or tree … 25
         - 25. Plant evergreen … 26
           - 26. Plant a shrub, often sticky; Flowers in dense clusters (surrounded by bracts so that they almost appear to be a single flower) developing into dry fruits with a tuft of bristles (pappus) at the top … 27
             - 27. Leaves up to 15 cm long, narrow with a gradual taper, widest near middle; Leaf stalks (petioles) winged (i.e., having a thin, flat extension running along them) … *Baccharis salicifolia* (mule fat)

27. Leaves up to 5 cm long, broad and strongly tapering to base, often widest above middle; Leaf stalks very short … *Baccharis pilularis* (coyote brush)

26. Plant a shrub or tree, not sticky; Flowers not as above, clearly on separate stalks (pedicels), and fruits fleshy … 28

28. Leaf margin entire (smooth); Fruits 1-3 cm long, green or black when mature … 29

29. Leaves alternate, green on both sides, aromatic … *Umbellularia californica* (California bay laurel)

29. Leaves opposite, green above, silvery below, not particularly aromatic … *Olea europea* (olive)

28. Leaf margin toothed; Fruits about 0.6 cm long, red when mature … *Heteromeles arbutifolia* (toyon)

25. Plant deciduous … 30

30. Leaves opposite or whorled … 31

31. Leaf margins jagged (toothed); Fruit 2-parted, each part with a wing (a thin flat extension), and not splitting open, seeds not hairy … *Acer saccharinum* (Silver maple)

31. Leaf margins smooth; Fruit lacking a wing, seeds with or without a fringe of hairs …

32. Fruits arranged in a dense ball at or near tips of branches, and each fruit composed of two hard, dry pieces; Seeds without a fringe of hairs; Plant a shrub or small tree; Leaves with a dry scale (interpetiolar stipule) between adjacent leaf bases … *Cephalanthus occidentalis* (Button-willow)

32. Fruit a long woody pod; Seeds with fringes of hairs at their ends; Plant a tree; Leaves without scales (stipules) at the base of their stalks … *Catalpa* species (common name also Catalpa)

30. Leaves alternate … 33

33. Leaves small (< 3mm), triangular and close against the stem; Petioles (leaf stalks) absent … *Tamarix parviflora* (Smallflower tamarisk)

33. Leaves larger (> 1 cm), shapes various but not triangular, and spreading away from stem; Petioles present … 34

34. Leaves lobed … 35

35. Leaves 2-5 cm wide and hairless, base of leaf stalk does not completely enclose bud; Plant a shrub … *Ribes aureum* (Golden currant)

35. Leaves 10-20 cm wide and pubescent, base of leaf stalk either encircles stem or completely encloses bud; Plant a large shrub to large tree … 36

36. Leaves and stems exude milky sap when broken; Fruit fleshy; Bark relatively smooth and not flaking … *Ficus carica* (Fig)

36. Leaves and stem do not exude milky sap when broken; Fruit hard and dry with a tuft of hairs, arranged in dense round heads; Bark flakes in thin sheets to reveal smooth pale surface … *Platanus racemosa* (Western sycamore)

34. Leaves toothed but not lobed; Bark varied but not as above; Fruits various but not as above ... 37

37. Leaves triangular to heart-shaped; Petiole (leaf stalk) flattened near leaf blade; Fruit a capsule opening to release small seeds in cottony fluff; Plant a large tree to 30 m … *Populus fremontii* (Fremont's cottonwood)

37. Leaves elliptic to lance-shaped; petiole more or less round, not conspicuously flattened; Fruit not a capsule and seeds not embedded in cottony fluff; Plant a small to large tree … 38

38. Plant with two types of shoots – long and short shoots, the short shoots with closely spaced leaves and also bearing the flowers and fruits; Leaves with lateral veins that fork and bend before reaching the leaf margin (the edge of the leaf) … *Prunus* species (the stone fruits including cherries and almond)

38. Plant with one type of shoot, though these may vary in orientation and spacing of leaves; Leaves with straight lateral veins only some of which fork before reaching the leaf margin … 39
    39. Fruits produced on woody scales arranged in a cone-like structure; Buds on a small stalk, not offset from leaf stalk … *Alnus rhombifolia* (White alder)
    39. Fruits not produced in a cone-like structure; Buds not stalked, offset from leaf stalk … *Ulmus* species (Elm species)

Appendix B

Summary of Species Observations

Table B-1. Frequency of Observed Odonate Species

Common Name	Scientific Name	Total (%) *N = 43*	Placer County Plots (%) *N = 20*	Other Plots (%) *N = 23*
Damselflies	**Zygoptera**			
American Rubyspot	*Hetaerina americana*	47	50	43
Spotted Spreadwing	*Lestes congener*	2	0	4
California Spreadwing	*Archilestes californica*	7	0	13
California Dancer	*Argia agrioides*	19	20	17
Emma's Dancer	*Argia emma*	28	25	30
Sooty Dancer	*Argia lugens*	14	5	22
Aztec Dancer	*Argia nahuana*	2	0	4
Vivid Dancer	*Argia vivida*	40	45	35
Unknown sp. teneral dancer	*Argia* sp.	5	10	0
Boreal Bluet	*Enallagma boreale*	5	5	4
Familiar Bluet	*Enallagma civile*	44	40	48
Unknown sp. female bluet	*Enallagma* sp.	5	5	4
Pacific Forktail	*Ischnura cervula*	42	35	48
Western Forktail	*Ischnura perparva*	5	10	0
Desert Firetail	*Telebasis salva*	2	5	0
Dragonflies	**Anisoptera**			
Blue-eyed Darner	*Aeshna multicolor*	65	75	57
Common Green Darner	*Anax junius*	93	90	96
Pale-faced Clubskimmer	*Brechmorhoga mendax*	42	50	35
Western Pondhawk	*Erythemis collocata*	26	20	30
Eight-spotted Skimmer	*Libellula forensis*	0	0	0
Widow Skimmer	*Libellula luctuosa*	9	10	9
Common Whitetail	*Plathemis lydia*	7	10	4
Twelve-spotted Skimmer	*Libellula pulchella*	9	5	13
Flame Skimmer	*Libellula saturata*	21	0	39
Blue Dasher	*Pachydiplax longipennis*	30	35	26
Red Rock Skimmer	*Paltothemis lineatipes*	5	0	9
Wandering Glider	*Pantala flavescens*	44	40	48
Spot-winged Glider	*Pantala hymenaea*	26	25	26
Variegated Meadowhawk	*Sympetrum corruptum*	51	40	61
Striped Meadowhawk	*Sympetrum pallipes*	5	0	9
Black Saddlebags	*Tramea lacerata*	84	85	83

Table B-2. Observed Butterfly Species

Common Name	Scientific Name	Total (%) *N = 43*	Placer County Plots (%) *N = 23*	Other Plots (%) *N = 24*
California Sister	*Adelpha bredowii*	11	13	8
Sara Orange-tip	*Anthocharis sara*	6	9	4
Field Skipper	*Atlopedes campestris*	23	35	13
Pipevine Swallowtail	*Battus philenor*	72	70	75
Persius Duskywing	*Erynnis persius*	2	0	4
Northern Checkerspot	*Charidryas palla*	4	4	4
California Ringlet	*Coenonympha tullia*	45	70	21
Orange Sulphur	*Colias eurytheme*	77	74	79
Monarch	*Danaus plexipus*	0	0	0
Propertius Duskywing	*Erynnis propertius*	6	4	8
Mournful Duskywing	*Erynnis tristis*	2	4	0
Common Checkerspot	*Euphydryas chalcedona*	4	0	8
Eastern Tailed Blue	*Everes comyntas*	51	57	46
Gorgon Copper	*Gaeides gorgon*	2	0	4
Fiery Skipper	*Hylephila phyleus*	6	13	0
Buckeye	*Junonia coenia*	96	96	96
Lorquin's Admiral	*Limentis lorquini*	15	30	0
Purplish Copper	*Lycaena helloides*	4	9	0
Mourning Cloak	*Nymphalis antiopa*	11	17	4
The Farmer	*Ochlodes agricola*	4	9	0
Pale Swallowtail	*Papilio eurymedon*	2	4	0
Western Tiger	*Papilio rutulus*	70	78	63
Anise Swallowtail	*Paplio zelicaon*	13	17	8
Umber Skipper	*Paratrytone melane*	13	22	4
Common sSoty-wing	*Pholisora catullus*	2	0	4
Mylitta Crescent	*Phyciodes mylitta*	34	52	17
Cabbage Butterfly	*Pieris rapae*	89	91	88
Acmon Blue	*Plebejus acmon*	30	17	42
Sandhill Skipper	*Polites sabuleti*	2	4	0
Satyr Comma	*Polygonia satyrus*	4	0	8
Checkered White	*Pontia protodice*	2	4	0
Common Checkered	*Pyrgus communis*	4	0	8
California Hairstreak	*Satyrium californicum*	17	17	17
Hedge-row Hairstreak	*Satyrium saepium*	0	0	0
Sylvan Hairstreak	*Satyrium sylvinus*	11	9	13
Common Hairstreak	*Strymon melinus*	28	48	8
West Coast Lady	*Vanessa annabella*	4	0	8
Red Admiral	*Vanessa atalanta*	34	43	25
Painted Lady	*Vanessa cardui*	55	61	50
American Lady	*Vanessa virginiensis*	6	13	0

Table B-3. Amphibian and Reptile Species Observed During One Survey of Plots

Common Name	Scientific Name	Total (%) *N = 47*	Placer County Plots (%) *N = 23*	Other Plots (%) *N = 24*
Pacific Treefrog	*Pseudacris regilla*	2	4	0
Foothill Yellow-legged Frog	*Rana boylii*	0	0	0
Bullfrog	*Rana catesbeiana*	32	26	38
Western Pond Turtle	*Emys marmorata*	0	0	0
Western Fence Lizard	*Sceloporus occidentalis*	28	26	29
Western Skink	*Eumeces skiltonianus*	0	0	0
Aligator Lizard	*Elgaria* sp.	13	4	21
Gopher Snake	*Pituophis catenifer*	2	0	4
Garter Snake	*Thamnophis* sp.	2	0	4
Western Rattlesnake	*Crotalis viridis*	6	4	8

Table B-4. Amphibian and Reptile Species Observed During Four Surveys of Plots

Common Name	Scientific Name	Total (%) *N = 12*	Placer County Plots (%) *N = 8*	Other Plots (%) *N = 4*
Pacific Treefrog	*Pseudacris regilla*	8	0	25
Foothill Yellow-legged Frog	*Rana boylii*	8	13	0
Bullfrog	*Rana catesbeiana*	42	38	50
Western Pond Turtle	*Emys marmorata*	8	0	25
Western Fence Lizard	*Sceloporus occidentalis*	83	88	75
Western Skink	*Eumeces skiltonianus*	0	0	0
Aligator Lizard	*Elgaria* sp.	33	50	0
Gopher Snake	*Pituophis catenifer*	8	13	0
Garter Snake	*Thamnophis* sp.	0	0	0
Western Rattlesnake	*Crotalis viridis*	8	0	25

Table B-5. Mammal Species Observed During One Survey of Plots

Common Name	Scientific Name	Total (%) *N = 47*	Placer County Plots (%) *N = 23*	Other Plots (%) *N = 24*
Virginian Opossum	*Didelphis virginiana*	2	0	4
Desert Cottontail	*Sylivlagus audubonii*	4	4	4
Black-tailed Jackrabbit	*Lepus californicus*	11	13	8
Western Gray Squirrel	*Sciurus griseus*	19	22	17
Botta's Pocket Gopher	*Thomomys bottae*	9	4	13
American Beaver	*Castor canadensis*	6	0	12.5
Coyote	*Canis latrans*	6	9	4
Racoon	*Procyon lotor*	40	35	46
Northern River Otter	*Lontra canadensis*	2	0	4
Bobcat	*Lynx rufus*	9	9	8
Mule Deer	*Odocoileus hemionus*	34	26	42

Table B-6. Mammal Species Observed During Four Surveys of Plots

Common Name	Scientific Name	Total (%) *N = 12*	Placer County Plots (%) *N = 8*	Other Plots (%) *N = 4*
Virginian Opossum	*Didelphis virginiana*	8	13	0
Desert Cottontail	*Sylivlagus audubonii*	8	0	25
Black-tailed Jackrabbit	*Lepus californicus*	17	13	25
Western Gray Squirrel	*Sciurus griseus*	33	38	25
Botta's Pocket Gopher	*Thomomys bottae*	8	0	25
Deer Mouse	*Peromyscus maniculatus*	8	0	25
California Meadow Mouse	*Microtus californicus*	17	13	25
Feral Dog	*Canis familiaris*	8	0	25
Coyote	*Canis latrans*	17	25	0
Gray Fox	*Urocyon cinereoargenteus*	8	0	25
Raccoon	*Procyon lotor*	75	75	75
Feral Cat	*Felis catus*	17	25	0
Bobcat	*Lynx rufus*	17	13	25
Mule Deer	*Odocoileus hemionus*	67	63	75
Muskrat	*Ondatra zibethicus*	8	0	25

Table B-7. Mean Abundance of Small Mammals Trapped at Plots[1]

Common Name	Scientific Name	Total *N = 10*	Placer County Plots *N = 6*	Other Plots *N = 4*
Opossum	*Didelphis virginiana*	0.1 ± 0.1	0.2 ± 0.2	–
Brush Mouse	*Peromyscus boylii*	3.5 ± 2.3	–	8.8 ± 5.1
Deer Mouse	*Peromyscus maniculatus*	5.1 ± 1.8	2.0 ± 1.6	9.8 ± 2.5
California Meadow Mouse	*Microtus californicus*	3.2 ± 2.5	1.2 ± 0.7	6.3 ± 6.3
House Mouse	*Mus musculus*	1.3 ± 0.9	0.8 ± 0.8	2.0 ± 2.0
Black Rat	*Rattus rattus*	0.6 ± 0.2	0.7 ± 0.3	0.5 ± 0.3

[1] Values are means ± 1 standard error.

Table B-8. Bird Species Observed During One Survey of Plots

Common Name	Scientific Name	Summer Resident	Migrant	Total (%) *N = 47*	Placer County Plots (%) *N = 23*	Other Plots (%) *N = 24*
Pied-billed Grebe	*Podilymbus podiceps*	X		2	4	0
Great Blue Heron	*Ardea herodias*	X		2	4	0
Green Heron	*Butorides virescens*	X		2	0	4
Wood Duck	*Aix sponsa*	X		2	4	0
Mallard	*Anas platyrhynchos*	X		11	17	4
Cinnamon Teal	*Anas cyanoptera*	X		2	4	0
Common Merganser	*Mergus merganser*	X		0	0	0
Turkey Vulture	*Cathartes aura*	X		4	4	4
White-tailed Kite	*Elanus leucurus*	X		2	0	4
Cooper's Hawk	*Accipiter cooperii*	X		2	4	0
Red-shouldered Hawk	*Buteo lineatus*	X		11	13	8
Swainson's Hawk	*Buteo swainsoni*	X		2	4	0
Red-tailed Hawk	*Buteo jamaicensis*	X		6	0	13
American Kestrel	*Falco sparverius*	X		0	0	0
Ring-necked Pheasant	*Phasianus colchicus*	X		2	4	0
Wild Turkey	*Meleagris gallopavo*	X		4	9	0
California Quail	*Callipepla californica*	X		17	13	21
Common Moorhen	*Gallinula chloropus*	X		2	4	0
American Coot	*Fulica americana*	X		2	4	0
Killdeer	*Charadrius vociferus*	X		9	4	13
Spotted Sandpiper	*Tringa macularia*	X		0	0	0
Mourning Dove	*Zenaida macroura*	X		28	26	29
Barn Owl	*Tyto alba*	X		0	0	0

Common Name	Scientific Name	Summer Resident	Migrant	Total (%) *N = 47*	Placer County Plots (%) *N = 23*	Other Plots (%) *N = 24*
Great Horned Owl	*Bubo virginianus*	X		0	0	0
Black-chinned Hummingbird	*Archilochus alexandri*	X		17	17	17
Anna's Hummingbird	*Calypte anna*	X		32	30	33
Belted Kingfisher	*Megaceryle alcyon*	X		11	9	13
Acorn Woodpecker	*Melanerpes formicivorus*	X		30	48	13
Nuttall's Woodpecker	*Picoides nuttallii*	X		60	52	67
Downy Woodpecker	*Picoides pubescens*	X		40	39	42
Hairy Woodpecker	*Picoides villosus*	X		2	0	4
Northern Flicker	*Colaptes auratus*	X		11	4	17
Western Wood-Pewee	*Contopus sordidulus*	X		32	26	38
Willow Flycatcher	*Empidonax traillii*		X	13	22	4
Dusky Flycatcher	*Empidonax oberholseri*		X	2	4	0
Pacific-slope Flycatcher	*Empidonax difficilis*	X		19	22	17
Black Phoebe	*Sayornis nigricans*	X		51	61	42
Ash-throated Flycatcher	*Myiarchus cinerascens*	X		68	70	67
Western Kingbird	*Tyrannus verticalis*	X		30	26	33
Hutton's Vireo	*Vireo huttoni*	X		9	13	4
Warbling Vireo	*Vireo gilvus*	?		28	30	25
Western Scrub-Jay	*Aphelocoma californica*	X		57	65	50
Yellow-billed Magpie	*Pica nuttalli*	X		19	26	13
American Crow	*Corvus brachyrhynchos*	X		2	4	0
Common Raven	*Corvus corax*	X		0	0	0
Tree Swallow	*Tachycineta bicolor*	X		38	26	50
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	X		15	4	25
Cliff Swallow	*Hirundo pyrrhonota*	X		4	0	8

Common Name	Scientific Name	Summer Resident	Migrant	Total (%) *N = 47*	Placer County Plots (%) *N = 23*	Other Plots (%) *N = 24*
Barn Swallow	*Hirundo rustica*	X		2	4	0
Oak Titmouse	*Parus inornatus*	X		53	61	46
Bushtit	*Psaltriparus minimus*	X		57	61	54
White-breasted Nuthatch	*Sitta carolinensis*	X		51	65	38
Bewick's Wren	*Thryomanes bewickii*	X		40	26	54
House Wren	*Troglodytes aedon*	X		55	74	38
Western Bluebird	*Sialia mexicana*	X		9	4	13
Swainson's Thrush	*Catharus ustulatus*		X	9	0	17
American Robin	*Turdus migratorius*	X		30	30	29
Wrentit	*Chamaea fasciata*	X		15	26	4
Northern Mockingbird	*Mimus polyglottos*	X		13	17	8
European Starling	*Sturnus vulgaris*	X		40	48	33
Cedar Waxwing	*Bombycilla cedrorum*		X	2	0	4
Phainopepla	*Phainopepla nitens*	X		0	0	0
Orange-crowned Warbler	*Vermivora celata*	X		19	22	17
Nashville Warbler	*Vermivora ruficapilla*		X	2	0	4
Yellow Warbler	*Dendroica petechia*		X	21	13	29
Common Yellowthroat	*Geothlypis trichas*	X		11	9	13
Wilson's Warbler	*Wilsonia pusilla*	?		30	17	42
Yellow-breasted Chat	*Icteria virens*	X		30	22	38
Western Tanager	*Piranga ludoviciana*		X	26	22	29
Black-headed Grosbeak	*Pheucticus melanocephalus*	X		45	35	54
Blue Grosbeak	*Guiraca caerulea*	X		4	0	8
Lazuli Bunting	*Passerina amoena*	X		19	22	17
Spotted Towhee	*Pipilo maculatus*	X		28	30	25

Common Name	Scientific Name	Summer Resident	Migrant	Total (%) *N = 47*	Placer County Plots (%) *N = 23*	Other Plots (%) *N = 24*
California Towhee	*Pipilo crissalis*	X		19	9	29
Lark Sparrow	*Chondestes grammacus*	X		2	0	4
Savannah Sparrow	*Passerculus sandwichensis*	X		2	0	4
Song Sparrow	*Melospiza melodia*	X		26	26	25
Red-winged Blackbird	*Agelaius phoeniceus*	X		13	17	8
Western Meadowlark	*Sturnella neglecta*	X		13	13	13
Brewer's Blackbird	*Euphagus cyanocephalus*	X		11	0	21
Brown-headed Cowbird	*Molothrus ater*	X		51	30	71
Bullock's Oriole	*Icterus bullockii*	X		32	13	50
House Finch	*Carpodacus mexicanus*	X		49	43	54
Lesser Goldfinch	*Carduelis psaltria*	X		45	57	33
American Goldfinch	*Carduelis tristis*	X		45	48	42
House Sparrow	*Passer domesticus*	X		9	9	8

Table B-9. Bird Species Observed During Four Site Visits

Common Name	Scientific Name	Summer Resident	Migrant	Total (%) *N = 12*	Placer County Plots (%) *N = 8*	Other Plots (%) *N = 4*
Pied-billed Grebe	*Podilymbus podiceps*	X		0	0	0
Great Blue Heron	*Ardea herodias*	X		0	0	0
Green Heron	*Butorides virescens*	X		8	13	0
Wood Duck	*Aix sponsa*	X		17	25	0
Mallard	*Anas platyrhynchos*	X		25	38	0
Cinnamon Teal	*Anas cyanoptera*	X		0	0	0
Common Merganser	*Mergus merganser*	X		8	0	25
Turkey Vulture	*Cathartes aura*	X		17	13	25
White-tailed Kite	*Elanus leucurus*	X		8	0	25
Cooper's Hawk	*Accipiter cooperii*	X		8	13	0
Red-shouldered Hawk	*Buteo lineatus*	X		42	63	0
Swainson's Hawk	*Buteo swainsoni*	X		8	0	25
Red-tailed Hawk	*Buteo jamaicensis*	X		25	13	50
American Kestrel	*Falco sparverius*	X		8	13	0
Ring-necked Pheasant	*Phasianus colchicus*	X		8	13	0
Wild Turkey	*Meleagris gallopavo*	X		0	0	0
California Quail	*Callipepla californica*	X		42	25	75
Common Moorhen	*Gallinula chloropus*	X		0	0	0
American Coot	*Fulica americana*	X		0	0	0
Killdeer	*Charadrius vociferus*	X		17	13	25
Spotted Sandpiper	*Tringa macularia*	X		8	0	25
Mourning Dove	*Zenaida macroura*	X		58	38	100
Barn Owl	*Tyto alba*	X		0	0	0

Table B-9. Continued

Common Name	Scientific Name	Summer Resident	Migrant	Total (%) *N = 12*	Placer County Plots (%) *N = 8*	Other Plots (%) *N = 4*
Great Horned Owl	*Bubo virginianus*	X		8	13	0
Black-chinned Hummingbird	*Archilochus alexandri*	X		58	50	75
Anna's Hummingbird	*Calypte anna*	X		67	88	25
Belted Kingfisher	*Megaceryle alcyon*	X		42	38	50
Acorn Woodpecker	*Melanerpes formicivorus*	X		83	88	75
Nuttall's Woodpecker	*Picoides nuttallii*	X		92	88	100
Downy Woodpecker	*Picoides pubescens*	X		75	88	50
Hairy Woodpecker	*Picoides villosus*	X		0	0	0
Northern Flicker	*Colaptes auratus*	X		17	25	0
Western Wood-Pewee	*Contopus sordidulus*	X		58	50	75
Willow Flycatcher	*Empidonax traillii*		X	33	38	25
Dusky Flycatcher	*Empidonax oberholseri*		X	8	13	0
Pacific-slope Flycatcher	*Empidonax difficilis*	X		33	50	0
Black Phoebe	*Sayornis nigricans*	X		92	88	100
Ash-throated Flycatcher	*Myiarchus cinerascens*	X		100	100	100
Western Kingbird	*Tyrannus verticalis*	X		33	13	75
Hutton's Vireo	*Vireo huttoni*	X		17	25	0
Warbling Vireo	*Vireo gilvus*	?		33	38	25
Western Scrub-Jay	*Aphelocoma californica*	X		75	75	75
Yellow-billed Magpie	*Pica nuttalli*	X		25	25	25
American Crow	*Corvus brachyrhynchos*	X		17	25	0
Common Raven	*Corvus corax*	X		8	0	25
Tree Swallow	*Tachycineta bicolor*	X		58	38	100
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	X		50	50	50
Cliff Swallow	*Hirundo pyrrhonota*	X		17	25	0

Common Name	Scientific Name	Summer Resident	Migrant	Total (%) *N = 12*	Placer County Plots (%) *N = 8*	Other Plots (%) *N = 4*
Barn Swallow	*Hirundo rustica*	X		0	0	0
Oak Titmouse	*Parus inornatus*	X		92	100	75
Bushtit	*Psaltriparus minimus*	X		100	100	100
White-breasted Nuthatch	*Sitta carolinensis*	X		92	100	75
Bewick's Wren	*Thryomanes bewickii*	X		83	88	75
House Wren	*Troglodytes aedon*	X		92	88	100
Western Bluebird	*Sialia mexicana*	X		17	13	25
Swainson's Thrush	*Catharus ustulatus*		X	8	0	25
American Robin	*Turdus migratorius*	X		67	75	50
Wrentit	*Chamaea fasciata*	X		33	38	25
Northern Mockingbird	*Mimus polyglottos*	X		25	13	50
European Starling	*Sturnus vulgaris*	X		92	100	75
Cedar Waxwing	*Bombycilla cedrorum*		X	8	13	0
Phainopepla	*Phainopepla nitens*	X		17	13	25
Orange-crowned Warbler	*Vermivora celata*	X		42	50	25
Nashville Warbler	*Vermivora ruficapilla*		X	8	0	25
Yellow Warbler	*Dendroica petechia*		X	25	25	25
Common Yellowthroat	*Geothlypis trichas*	X		17	0	50
Wilson's Warbler	*Wilsonia pusilla*	?		58	50	75
Yellow-breasted Chat	*Icteria virens*	X		42	38	50
Western Tanager	*Piranga ludoviciana*		X	58	50	75
Black-headed Grosbeak	*Pheucticus melanocephalus*	X		83	88	75
Blue Grosbeak	*Guiraca caerulea*	X		0	0	0
Lazuli Bunting	*Passerina amoena*	X		25	25	25
Spotted Towhee	*Pipilo maculatus*	X		67	63	75

Common Name	Scientific Name	Summer Resident	Migrant	Total (%) *N = 12*	Placer County Plots (%) *N = 8*	Other Plots (%) *N = 4*
California Towhee	*Pipilo crissalis*	X		25	25	25
Lark Sparrow	*Chondestes grammacus*	X		0	0	0
Savannah Sparrow	*Passerculus sandwichensis*	X		0	0	0
Song Sparrow	*Melospiza melodia*	X		42	38	50
Red-winged Blackbird	*Agelaius phoeniceus*	X		0	0	0
Western Meadowlark	*Sturnella neglecta*	X		0	0	0
Brewer's Blackbird	*Euphagus cyanocephalus*	X		8	0	25
Brown-headed Cowbird	*Molothrus ater*	X		75	63	100
Bullock's Oriole	*Icterus bullockii*	X		58	50	75
House Finch	*Carpodacus mexicanus*	X		83	75	100
Lesser Goldfinch	*Carduelis psaltria*	X		92	100	75
American Goldfinch	*Carduelis tristis*	X		75	88	50
House Sparrow	*Passer domesticus*	X		25	25	25

Appendix B

Central Valley Songbird Responses to Riparian Width and Other Site- and Landscape-Scale Habitat Characteristics

Appendix B

Central Valley Songbird Responses to Riparian Width and Other Site- and Landscape-Scale Habitat Characteristics

Introduction

To address Placer County's interest in developing riparian setback guidelines for conservation purposes, we analyzed six years of riparian bird count data with respect to width of the riparian zone. Using a subset of PRBO bird survey sites, supplemented by new sites in Placer County, Jones & Stokes (2004) detected a positive relationship between riparian bird species richness and riparian zone width. Thus we wanted to investigate whether additional relationships could be detected using our comprehensive Central Valley riparian point count dataset. In our analysis, we also examined local vegetation and GIS-generated habitat types and surrounding landscape characteristics. Our primary goal was to characterize songbird relationships with riparian zone width, and to identify appropriate widths for riparian buffer zones (development setbacks), given a range of habitat and landscape characteristics.

Methods

Data used for analysis were obtained from bird point count surveys (Ralph et al. 1993) conducted between 1998 and 2003. Sites included long-term monitoring sites along the Sacramento, Cosumnes and San Joaquin Rivers, as well as sites that were surveyed for shorter periods of time, primarily for inventory purposes (Figure B-1). We used a total of 596 riparian point count stations along 117 streamside transects (Table B-1). Within each transect, points were spaced at least 200 meters apart, and the first point count survey station was selected using a random starting point. Point counts were conducted for five minutes, with 1-3 visits per season. (See http://www.prbo.org/tools/pc/pcprot.doc for detailed methods.)

For each of the 596 survey points, we calculated riparian species richness (as defined in Jones & Stokes 2004) as a cumulative value across all surveys. We also obtained a mean abundance across all surveys for each of these riparian-associated species, as well as presence/absence. A variable representing the number of surveys upon which the species richness and presence/absence values were based was retained in all models, to account for the fact that species richness increases with the number of surveys.

Using standard GIS data layers, point count stations were classified into two general categories, tributary or mainstem, as well as identified by drainage basin (DWR CalWater 2.2), elevation, and dominant vegetation cover type (WHR category based on best available GIS data layer) (Tables B-2 to B-5).

For each point we also calculated surrounding landscape characteristics within a 1-km radius, as well as the dominant surrounding land use—urban, agricultural, or "natural" (everything else). Land use and vegetation types were aggregated into more meaningful categories for analysis (Table B-5). We used three different GIS layers for these calculations:

1. Land use (DWR multi-year composite) (Figure B-2)
2. Vegetation (CDFG/DU 1993 wetlands where available; USFS existing vegetation multi-year composite elsewhere) (Figure B-3)
3. Riparian vegetation (union of available datasets: Chico State Sacramento River, San Joaquin River, CDFG/DU wetlands, DWR land use, Placer County vegetation)

Vegetation data were collected for each point count location using a modified relevé protocol (Ralph et al. 1993, Ralph et al. 1995) within a 50-m radius (see http://www.prbo.org/tools/pc/relevepr.html for detailed methods). A subset of variables representing major structural characteristics was used for this analysis (Table B-5). To reduce the number of variables considered, and because riparian zone width was of primary interest in our analysis, floristic composition variables were not analyzed.

Regression models were developed for riparian-associated bird species richness (as defined by Jones & Stokes 2004), as well as presence/absence of each of these species. We used multiple linear regression for species richness, and logistic regression (Hosmer and Lemeshow 1989) for each individual species' occurrence. Three classes of regression models were developed and compared with respect to the relative importance of riparian width as a predictor of bird species richness / occurrence. The dependent variables for each of these model classes were:

- Riparian width category only
- Riparian width category + potentially significant vegetation and landscape variables (from Pearson correlation analysis, $\alpha = 0.10$)
- Riparian width category + basin, vegetation type (WHR) and stream type

Models were first constructed using a numerical riparian width value (1 = 0-50 m, 2 = 50-100 m, 3 = >100 m), treated as a continuous variable, to test for linear relationships between riparian width and bird species richness and individual species' probability of occurrence. To evaluate differences between each of our three width categories (<50 m, 50-100 m, >100 m), we reran the models treating

Table B-1. Site Summary

Transect Code	Transect Name	County	Basin Name	Number of Points	Number of Visits	Number of Years
ANRP	Anderson River Park	Shasta	Redding	3	1	1
BACR	Battle Creek Parking	Tehama	Redding	15	6	3
BASL	Babel Slough	Yolo	Sacramento Delta	6	1	1
BEHI	Beehive	Glenn	Colusa Basin	6	4	2
BISO	Bloody Island South	Tehama	Redding	4	2	1
BIVI	Bianchi Vineyards	Fresno	South Valley Floor	3	1	1
BRSP	Bidwell-Sacramento River Park	Butte	Tehama	15	4	2
BUCR	Butte Creek	Shasta	Colusa Basin	4	1	1
BUPA	Bussett Park	Kings	South Valley Floor	1	1	1
BUSI	Butte Sink	Shasta	Colusa Basin	2	1	1
CAPA	Camp Pashayan	Fresno	South Valley Floor	2	2	1
CARO	Carpenter Road	Stanislaus	San Joaquin Valley Floor	2	2	1
CCRD	Coal Canyon Road		Colusa Basin	1	1	1
CHCA	Chowchilla Canal	Madera	San Joaquin Valley Floor	10	2	1
CMAT	Cal Mat Cement	Kings	South Valley Floor	9	2	1
CMIN	Calveras Material, Inc.	Merced	San Joaquin Valley Floor	6	2	1
CMSP	Caswell Memorial State Park	San Joaquin	San Joaquin Valley Floor	15	2	1
CNWR	Colusa National Wildlife Refuge	Colusa	Colusa Basin	1	1	1
CODO	Codora	Glenn	Colusa Basin	6	21	7
COLU	Colusa	Colusa	Colusa Basin	7	5	2
COTT	Cottonwood Creek	Shasta	Redding	4	1	1
DCER	Deer Creek at Elliot Road	Sacramento	North Valley Floor	1	1	1

Transect Code	Transect Name	County	Basin Name	Number of Points	Number of Visits	Number of Years
DECR	Deer Creek	Tehama	Tehama	23	6	3
DNWR	Delevan National Wildlife Refuge	Colusa	Colusa Basin	1	1	1
DUFE	Durham Ferry	San Joaquin	San Joaquin Delta	11	2	1
DWRE	Dept. Water Resources	Sacramento	North Valley Floor / San Joaquin Delta	9	23	8
DYCR	Dye Creek	Tehama	Tehama	15	7	3
EFYE	Effie Yeaw County Park	Sacramento	Valley-American	5	2	1
ELAV	Elkhorn Avenue	Kings	South Valley Floor	3	1	1
ELKH	Elkhorn Regional Park	Yolo	Valley Putah-Cache	3	1	1
ENCI	Encinal	Sutter / Yolo	Marysville	3	1	1
ERRO	Evans Reimer Road	Butte	Marysville	1	1	1
FGLS	Fish and Game Llano Seco		Colusa Basin	1	1	1
FIRE	Firebaugh	Madera	San Joaquin Valley Floor	2	2	1
FLYN	Flynn	Tehama	Tehama	14	24	8
FMRO	Four Mile Road		Colusa Basin	1	1	1
FOCO	Four Corners	Merced	San Joaquin Valley Floor	3	2	1
GJHA	Grayson	Stanislaus	San Joaquin Valley Floor	6	2	1
GRAY	Green Field	Stanislaus	Delta-Mendota Canal	5	2	1
GRKL	Grimes to Knights Landing	Colusa / Sutter / Yolo	Colusa Basin / Valley-American	4	1	1
GRLO	Gray Lodge	Butte	Colusa Basin	2	1	1
GVGA	Great Valley Grasslands A	Merced	San Joaquin Valley Floor	3	2	1
GVGB	Great Valley Grasslands B	Merced	Delta-Mendota Canal	3	2	1

Transect Code	Transect Name	County	Basin Name	Number of Points	Number of Visits	Number of Years
HALE	Haleakala	Tehama	Tehama	6	23	8
HAPA	Halgaman Park	Stanislaus	San Joaquin Valley Floor	1	1	1
HAYE	Hayes Avenue	Kings	South Valley Floor	5	1	1
HBRA	Honolulu Bar Recreation Area	Stanislaus	San Joaquin Valley Floor	1	2	1
HOSL	Howard Slough (F&G)		Colusa Basin	3	1	1
HW41	Highway 41	Fresno	South Valley Floor	3	1	1
JACI	Jacinto	Glenn	Colusa Basin	9	3	2
JFBR	Jelly's Ferry Bridge	Tehama	Redding	2	2	1
KAIS	Kaiser	Glenn	Tehama	8	9	3
KCCD	Kings County Conservation District	Kings	South Valley Floor	1	2	1
KOSL	Kopta Slough	Tehama	Tehama	6	17	6
LABA	La Baranca	Tehama	Tehama	15	23	8
LASL	Laird's Slough	Stanislaus	Delta-Mendota Canal	6	2	1
LBCR	Little Butte Creek	Butte	Colusa Basin	1	2	2
LIAV	Lincoln Avenue	Kings	South Valley Floor	1	1	1
LKRP	Layton-Kingston Regional Park	Fresno	South Valley Floor	2	1	1
LLSE	Llano Seco	Butte	Colusa Basin	5	5	3
LODI		Sacramento	North Valley Floor	3	1	1
LOLA	Lost Lake Park	Fresno	San Joaquin Valley Floor	13	2	1
LWWT	Livingston Waste Water Treatment	Merced	San Joaquin Valley Floor	1	1	1
MARO	Maple Road	Fresno	South Valley Floor	1	1	1
MEND	Mendota	Fresno	Delta-Mendota Canal / San Joaquin	4	2	1

Transect Code	Transect Name	County	Basin Name	Number of Points	Number of Visits	Number of Years
			Valley Floor			
MHRA	McHenry Recreation Area	San Joaquin	San Joaquin Valley Floor	4	2	1
MICR	Mill Creek	Tehama	Tehama	17	8	4
MOKE		Sacramento	North Valley Floor	1	1	1
MOON	Mooney	Tehama	Tehama	9	2	1
MORI	Mokelumne River	San Joaquin	North Valley Floor	6	1	1
MRBR	Meiss Road Bridge	Sacramento	North Valley Floor	1	1	1
MSRA	McConnel State Recreation Area	Merced	San Joaquin Valley Floor	5	2	1
OABR	Oakdale Avenue Bridge	Merced	San Joaquin Valley Floor	1	2	1
OBRA	Orange Blossom Recreation Area	Stanislaus	San Joaquin Valley Floor	2	2	1
OFBN	Ord Ferry Bridge North	Glenn	Colusa Basin	4	2	1
OLMI	Old Mill	Shasta	Redding	8	3	1
OSFA		Shasta	Redding	2	1	1
OWAR	Oroville Wildlife Area	Butte / Tehama	Marysville	10	2	2
PACR	Paine's Creek	Tehama	Redding	9	2	1
PAIS	Packer Island	Tehama	Colusa Basin	6	6	2
PARO	Parallel Road	San Joaquin	San Joaquin Valley Floor	3	2	1
PICR	Pine Creek	Butte	Tehama	7	11	4
PRAR	Project Area	Shasta	Redding	13	11	4
PRIN	Princeton	Colusa	Colusa Basin	7	3	2
PUCR	Putah Creek	Tehama	Valley Putah-Cache	3	1	1
PURO	Putnam Road	Colusa	Colusa Basin	2	1	1

Transect Code	Transect Name	County	Basin Name	Number of Points	Number of Visits	Number of Years
QSTR	Q Street	Fresno	Delta-Mendota Canal	1	2	1
RAMI	Ramirez	Fresno	Delta-Mendota Canal	1	1	1
RANK	Rank Island	Fresno	San Joaquin Valley Floor	3	1	1
REBA	Reading Bar	Shasta	Redding	4	11	4
REIS		Shasta	Redding	4	1	1
RIVI	River Vista	Tehama	Tehama	1	25	9
RSPO	Ripon Sewage Ponds	San Joaquin	San Joaquin Valley Floor	6	2	1
RYAN	Ryan	Tehama	Tehama	4	24	8
SACC	Sacramento River	Shasta	Redding	7	9	3
SFBR	Sante Fe Bridge	Stanislaus	San Joaquin Valley Floor	1	1	1
SHFA	Shiloh Fishing Access	Stanislaus	San Joaquin Valley Floor	1	1	1
SHGA	Shooting Gallery	Shasta	Redding	5	12	4
SRCL	Sacramento Refuge Car Loop		Colusa Basin	1	1	1
SRSL	Santa Rita Slough	Merced	Delta-Mendota Canal	1	2	1
STCR	Stony Creek	Glenn	Colusa Basin	6	23	8
STIL	Stillwater Creek	Shasta	Redding	1	1	1
SUNO	Sul Norte	Glenn	Colusa Basin	10	24	8
TAFO	Tall Forest	Sacramento	San Joaquin Delta	13	25	9
TAMO	Table Mountain	Tehama	Redding	7	1	1
THCR	Thomes Creek	Shasta / Tehama	Tehama	11	1	1
THOM	Thomas	Glenn	Colusa Basin	5	6	3
TLSR	Turlock Lake State Rec Area	Stanislaus	San Joaquin Valley Floor	4	2	1

Transect Code	Transect Name	County	Basin Name	Number of Points	Number of Visits	Number of Years
TURL	Turlock Road	Merced	San Joaquin Valley Floor	1	2	1
VALE	Valensin	Sacramento	North Valley Floor	5	20	7
VORA	Valley Oak Recreation Area	Stanislaus	San Joaquin Valley Floor	2	2	1
WELE	Wendell's Levee	Sacramento	San Joaquin Delta	3	25	9
WERO	Wendell's Road	Sacramento	North Valley Floor / San Joaquin Delta	3	23	9
WILA	Wilson's Landing	Butte	Tehama	3	1	1
WISL	Willow Slough	Sacramento	San Joaquin Delta	9	24	9
WIUN	Willow Unit	Fresno	San Joaquin Valley Floor	2	2	1
WOBR	Woodson Bridge State Park	Tehama	Tehama	13	5	3

Table B-2. Summary of Point Count Types -- Stream Type by Hydrologic Unit / Basin

Hydrologic Unit Name	Mainstem	Tributary	Total
Colusa Basin / Marysville	89	13	102
North Valley Floor / San Joaquin Delta	58	7	65
Redding	27	61	88
San Joaquin Valley Floor / Delta-Mendota Canal	117	2	119
South Valley Floor	31	0	31
Tehama	95	72	167
Valley-American / Valley Putah-Cache / Sacramento Delta	15	3	18
Total	432	158	590

Table B-3. Summary of Point Count Types -- Land Use Type by Hydrologic Unit / Basin

Hydrologic Unit Name	Agricultural	Natural	Urban	Total
Colusa Basin / Marysville	57	44	1	102
North Valley Floor / San Joaquin Delta	19	45	3	65
Redding	6	75	7	88
San Joaquin Valley Floor / Delta-Mendota Canal	77	39	3	119
South Valley Floor	20	11	0	31
Tehama	118	49	0	167
Valley-American / Valley Putah-Cache / Sacramento Delta	13	0	5	18
Total	310	263	19	590

Table B-4. Summary of Point Count Types -- WHR Habitat Type by Hydrologic Unit / Basin

Hydrologic Unit Name	AGR	AGS	BOW	CHP
Colusa Basin / Marysville	22	7	0	1
North Valley Floor / San Joaquin Delta	3	14	0	0
Redding	3	10	11	0
San Joaquin Valley Floor / Delta-Mendota Canal	14	18	1	0
South Valley Floor	2	8	0	1
Tehama	34	27	0	0
Valley-American / Valley Putah-Cache / Sacramento Delta	7	3	0	1
Total	85	87	12	3

Hydrologic Unit Name	FEW	URB	VOW	VRI	Total
Colusa Basin / Marysville	3	1	0	67	102
North Valley Floor / San Joaquin Delta	22	3	0	23	65
Redding	6	1	5	52	88
San Joaquin Valley Floor / Delta-Mendota Canal	9	3	0	75	119
South Valley Floor	1	2	0	17	31
Tehama	1	1	3	101	167
Valley-American / Valley Putah-Cache / Sacramento Delta	0	2	0	5	18
Total	42	13	8	340	590

Notes:

AGR = Agriculture

AGS = Annual Grassland

BOW = Blue Oak Woodland

CHP = Chaparral Scrub

FEW = Fresh Emergent Wetland

URB = Urban

VOW = Valley Oak Woodland

VRI = Valley / Foothill Riparian

Table B-5. Definition of Independent Variables Used in Regression Analysis

Variable name	Definition
Riparian width (field-collected)	
width2	riparian width category: 1 is 0-50 m, 2 is 50-100 m, 3 is >100 m)
Geography / habitat variables	
elevation	elevation (m)
huname / huname2	basin name (see Tables 2-4)
whr_new	WHR habitat type (see Table 4)
strm_type	stream type (mainstem or tributary)
Landscape-level vegetation variables	
rip_cov	proportion of riparian cover within a 1 km radius
agric_veg	proportion of agricultural vegetation within a 1 km radius
herb_veg	proportion of grassland vegetation within a 1 km radius
shrub_veg	proportion of shrub vegetation within a 1 km radius
wtlnd_veg	proportion of wetland vegetation within a 1 km radius
forest_veg	proportion of forest vegetation within a 1 km radius
Lanscape-level landuse variables	
agric_use	proportion of agricultural landuse within a 1 km radius
natur_use	proportion of natural landuse within a 1 km radius
urban_use	proportion of urban landuse within a 1 km radius
Site-level (field-collected) vegetation variables	
canopycov	canopy cover
treecov_new	absolute percent cover of the tree layer (>5 m in height); may contain vegetation that is not strictly a tree, such as vines hanging from trees, so long as its within the height range
shrubcov_new	absolute percent cover of the shrub layer (0.5-5 m in height); may contain non-woody plants within the height range
herbcov_new	absolute percent cover of the hebraceous layer (<0.5 m in height); may contain small shrubs and other woody plants less than .5 meters high
hitreeht	*average* height of the upper bounds of the tree layer
hishrubht	*average* height of the upper bounds of the shrub layer
maxtrdbh	maximum diameter at breast height to the nearest 0.1 centimeters, for the tree layer

width as a categorical variable and tested for equality of means within each width category.

This process was repeated for just the subset of point counts representing tributary streams, as well as for the subsets of data representing each dominant land use type within 1 km (agriculture, natural or urban).

Because we were interested in the effect of riparian width, with and without controlling for environmental conditions, we compared the model coefficient for riparian width across the three model classes. We recognized that riparian width could be affected by surrounding landscape characteristics, which may in turn affect local vegetation characteristics. Thus the apparent effect of riparian width could increase or decrease when controlling for other variables that are more strongly associated with a given bird metric. Our approach was intended to identify additional environmental variables associated with the bird metrics in question, and perhaps help explain the importance of riparian width. But we also wished to detect the responses to riparian width that may be obscured by other variables in a more complex model.

Results

Without controlling for any other environmental variables, riparian width was a significant positive predictor of riparian-associated bird species richness, as well as the presence of Black-headed Grosbeak (BHGR) and Common Yellowthroat (COYE) (Table B-6). Blue Grosbeak (BLGR) presence was negatively associated with riparian width. Controlling for the effect of geography (basin, elevation) and habitat type (WHR type and stream type), all of these species except COYE had a reduced, but still significant response to riparian width category, as did species richness. Only BHGR was positively associated with riparian width, and BLGR was negatively associated with riparian width, after also controlling for vegetation and surrounding land use characteristics (Table B-6).

Species richness and BHGR presence were positively associated with riparian width at mainstem, but not tributary sites, while the reverse was true for Yellow Warbler (YWAR) and COYE (Table B-7). For the Song Sparrow (SOSP), there was a significant positive relationship with riparian width at tributary sites, but a negative relationship at mainstem sites (Table B-7). BLGR presence was negatively associated with riparian width only at mainstem sites (Table B-7).

Comparing dominant surrounding land use categories (agricultural or natural), the relative importance of riparian width varied across species. For species richness, the effect was greater in natural than agricultural landscapes (Table B-8). For BHGR and BLGR probability of occurrence, the positive/negative effect of riparian width was greatest in natural landscapes. Warbling Vireo (WAVI) displayed a negative association with riparian width only in natural landscapes, while COYE and SOSP showed significant associations with riparian width only within agricultural landscapes (Table B-8).

Controlling for riparian width and site vegetation, we found a positive association between species richness and the proportion of riparian and wetland vegetation within a 1 km radius (Table B-10). With respect to individual species, we found that (Table B-10):

- YWAR was negatively associated with surrounding agricultural proportion within 1 km;
- BHGR and YWAR were negatively associated with surrounding grassland proportion;
- BLGR was positively associated with surrounding grassland proportion;
- SOSP and YBCH were positively associated with the proportion of surrounding natural land uses;
- YBCH was negatively associated with surrounding wetland proportion; and
- WIFL was positively associated with the proportion of surrounding forest.

Although we found a positive, linear effect of riparian width on species richness, tests for equality of means revealed a significant difference between widths greater than 100 m and those less than 100 m, but could not discriminate between widths less than 100 m (i.e., <50 m vs. 50-100 m) (Table B-6, Figure B-4). The same was true for YWAR and COYE probability of occurrence (Table B-7). However, for BHGR probability of occurrence, there was a threshold at 50 m, with a significant difference between width categories 1 (<50 m) and 2 (50-100 m), as well as between category 3 (>100 m) and category 1 (<50 m).

Summary and Recommendations

Our results indicated that, in California's Central Valley, the number of riparian songbird species was significantly lower where the riparian woodland zone was less than 100 m in width, at least along mainstem river corridors. Four species were also less likely to occur in riparian areas less than 100 m wide: the Black-headed Grosbeak, Common Yellowthroat, Yellow Warbler (a California Bird Species of Special Concern), and Song Sparrow. For the latter three species, this positive response to riparian width was only detected along tributary creeks, while for the Black-headed Grosbeak, it was only along mainstem rivers.

In addition, we found a strong influence of surrounding land use (within a 1-km radius) on which and how many riparian songbird species occurred at a site. The number of species increased with the amount of riparian and wetland habitat found within a 1-km radius. With respect to species composition, we found that the Yellow Warbler was negatively associated with the amount of agricultural land use within 1 km, and that the Song Sparrow and Yellow-breasted Chat were positively associated with the amount of “natural” (i.e., non-agricultural and non-urban) land use. Because few of our study sites were in urban areas, we were not able to evaluate the effect of urban development directly.

Table B-6. Comparison of Riparian Width Effect -- Univariate Models vs. Basin/Habitat Models vs. Vegetation/Landscape Models

		Univariate Model						Basin/Habitat Model						Veg/Landscape Model					
Bird Metric	Total Detections	Coeff	SE	Width test (1)	R2	P-value	n	Coeff	SE	Width test (1)	R2	P-value	n	Coeff	SE	Width test (1)	R2	P-value	n
Species Richness	N/A	0.40	0.08 ***	3>1*	0.67	<0.001	590	0.17	0.00 *	3>1*	0.72	0.01	590	0.13	0.09		0.71	0.15	556
BHGR presence	1499	0.70	0.12 ***	2>1*, 3>1**	0.24	<0.001	590	0.45	0.13 ***	2>1**, 3>1***	0.34	<0.001	587	0.37	0.14 *	2>1*, 3>1**	0.36	<0.001	560
BLGR presence	133	-0.60	0.17 ***		0.14	0.23	590	-0.59	0.19 **	3<1**	0.23	0.05	547	-0.37	0.19 *	3<1*	0.17	0.54	560
COYE presence	603	0.28	0.16 *	3>1*	0.04	<0.001	590	0.24	0.19		0.39	0.01	550	0.15	0.18		0.35	0.00	579
SOSP presence	957	-0.07	0.11		0.00	0.50	590	0.04	0.16 *		0.33	0.06	403	-0.22	0.12 *	3<1*	0.08	0.05	578
SWHA presence	15	0.11	0.60		0.17	0.33	590												
WIFL presence	43	0.07	0.22		0.08	0.42	590							-0.09	0.23		0.09		560
WAVI presence	124	-0.04	0.19		0.23	0.02	590	-0.21	0.22		0.31	0.67	548	-0.03	0.20		0.28	0.27	560
YBCH presence	227	0.08	0.15		0.04	0.14	590	-0.02	0.19		0.21	0.36	415	-0.13	0.17		0.24	0.54	560
YWAR presence	212	0.21	0.16		0.13	0.00	590	0.10	0.19		0.27	0.02	532	-0.04	0.20		0.24	0.27	558

* = P<0.10
** = P<0.01
*** = P<0.001

(1) 1 = 0-50 m
2 = 50-100 m
3 = > 100 m

Table B-7. Effect of Riparian Width -- Comparison Between Tributary and Mainstem Streams

		Univariate Model							Basin/Habitat Model						
Bird Metric		Coeff	SE		P-value	Width test	R2	n	Coeff	SE		P-value	Width test	R2	n
Species Richness	Mainstem	0.47	0.09	***		3>1***	0.71	432	0.14	0.09			3>1*	0.77	432
	Tributaries	0.23	0.15		0.13		0.50	158	0.16	0.15		0.28		0.59	158
BHGR presence	Mainstem	0.88	0.15	***		2>1*, 3>1***	0.12	432	0.56	0.18	**		2>1*, 3>1**	0.42	425
	Tributaries	-0.44	0.33		0.02		0.03	158	0.25	0.22		0.05		0.26	154
BLGR presence	Mainstem	-0.69	0.21	***		3<1***	0.18	432	-0.64	0.24	**		3<1**	0.28	376
	Tributaries	-0.44	0.33		0.27		0.03	158	-0.23	0.35		0.51		0.12	136
COYE presence	Mainstem	0.12	0.20		0.01		0.35	432	-0.17	0.25				0.41	385
	Tributaries	0.64	0.33	*		3>1*	0.21	158	0.98	0.39	*	0.01	3>1*	0.34	130
SOSP presence	Mainstem	-0.57	0.14	***		3<2*, 3<1***	0.06	432	-0.05	0.18				0.35	321
	Tributaries	0.84	0.32	**	0.00	3<1*	0.13	158	0.25	0.55		0.13		0.43	75
WAVI presence	Mainstem	0.16	0.24				0.28	432	0.12	0.29				0.35	388
	Tributaries	-0.63	0.37	*	0.16	3<2**	0.06	158	-0.60	0.42		0.32		0.15	115
YBCH presence	Mainstem	0.27	0.27				0.07	432	-0.38	0.32				0.15	258
	Tributaries	0.20	0.21		0.12		0.06	158	0.17	0.27		0.24		0.30	143
YWAR presence	Mainstem	-0.01	0.30				0.19	432	0.07	0.24				0.25	371
	Tributaries	0.68	0.29	*	0.01	3>1*	0.11	158	0.23	0.37		0.37		0.39	140

* = P<0.10
** = P<0.01
*** = P<0.001
(1) 1 = 0-50 m; 2 = 50-100 m; 3 = > 100 m

Table B-8. Riparian Width Effect -- Comparison between Predominantly Agricultural and Predominantly Natural Surrounding Land Uses

Bird Metric		Univariate Model Coeff	SE		Width tests (1)	R^2	n
Species Richness	Natural	0.50	0.10	***	3>1***, 3>2*	0.72	263
	Agricultural	0.31	0.12	**	3>1**	0.64	310
Black-headed Grosbeak presence	Natural	0.92	0.19	***	3>1***, 3>2*	0.22	263
	Agricultural	0.55	0.16	***	3>1**	0.28	310
Blue Grosbeak presence	Natural	-0.77	0.28	**	3<1**	0.21	263
	Agricultural	-0.48	0.22	*	3<1*	0.09	310
Common Yellowthroat presence	Natural	0.19	0.33			0.48	263
	Agricultural	0.38	0.19	*	3>1*	0.24	310
Song Sparrow presence	Natural	-0.02	0.19			0.16	263
	Agricultural	-0.52	0.17	**	3<2*, 3<1**	0.04	310
Warbling Vireo presence	Natural	-0.20	0.26			0.20	263
	Agricultural	0.08	0.31			0.33	310
Yellow-breated Chat presence	Natural	0.01	0.18			0.00	263
	Agricultural	0.16	0.34			0.23	310
Yellow Warbler presence	Natural	0.14	0.23			0.15	263
	Agricultural	0.15	0.27			0.15	310

Notes:

* = P<0.10
** = P<0.01
*** = P<0.001

(1)
1 = 0-50 m
2 = 50-100 m
3 = > 100 m

Table B-9. Significant Variables in Basin/Habitat Models

Bird Metric	n	R2 / Pseudo R2	Number of visits	Riparian width	Basin (1)	WHR Type (2)	Tributary	Elevation
Species Richness	590	0.72	+++		3(+++), 4(---), 6(+++), 7(--)	5(+++), 8(+++)	-	---
Black-headed Grosbeak presence	587	0.34	+++	+++	2(---), 4(---), 5(---), 7(-)		---	
Blue Grosbeak presence	547	0.23	+++	--	2(++), 5(+), 6(+)			
Common Yellowthroat presence	550	0.39	+++		3(+), 6(+)	6(+)		---
Song Sparrow presence	403	0.33	+++		2(+++), 3(+++), 4(+++), 5(+++)	3(-), 7(-), 8(---)		
Warbling Vireo presence	548	0.31	+++		6(+), 7(+)	3(++), 4(+), 8(+)	-	
Yellow-Breasted Chat presence	415	0.21	+++		2(--), 6(-)	2(+)	+	
Yellow Warbler presence	532	0.27	+++		6(-)	5(+++)		+

Notes:

+/- : P<0.10; ++/-- : P<0.01; +++/--- : P<0.001

(1) 1 = Colusa Basin / Marysville, 2 = North Valley Floor / San Joaquin Delta, 3 = Redding, 4 = San Joaquin Valley Floor / Delta-Mendota Canal, 5 = South Valley Floor, 6 = Tehama, 7 = Valley-American / Valley Putah-Cache / Sacramento Delta

(2) 1 = Agriculture (AGR), 2 = Annual Grassland (AGS), 3 = Blue Oak Woodland (BOW), 4 = Chaparral (CHP), 5 = Fresh Emergent Wetland (FEW), 6 = Urban (URB), 7 = Valley Oak Woodland (VOW), 8 = Valley/Foothill Riparian

Table B-10. Significant Independent Variables in Vegetation/Landscape Models

Bird Metric	n	R2 / Pseudo R2	Number of visits	Riparian width	Vegetation variables (2)	Landscape variables (2)
Species Richness	550	0.71	+++		maxtrdbh (+++), shrubcov_new (+++), herbcov_new (--)	rip_cov (+++), wtlnd_veg (+++)
Black-headed Grosbeak presence	560	0.36	+++	++	rip_cov (+++)	herb_veg (---)
Blue Grosbeak presence	560	0.17	+++	-	rip_cov (-)	herb_veg (+)
Common Yellowthroat presence	587	0.35	+++		shrubcov_new (+++)	
Song Sparrow presence	578	0.08	+++	-	treecov_new (-)	natur_use (+)
Swainson's Hawk presence	-					
Willow Flycather presence	560	0.09	++			forest_veg (+++)
Warbling Vireo presence	560	0.28	+++			shrub_veg (-), forest_veg (+), agric_use (-)
Yellow-breasted Chat presence	560	0.24	+++			shrub_veg (++), wtlnd_veg (---), natur_use (+++)
Yellow Warbler presence	558	0.25	+++		herbcov_new (-)	herb_veg (--), agric_use (---)

+/- = P<0.10

++/-- = P<0.01

+++/--- = P<0.001

(1) 1 = 0-50 m
2 = 50-100 m
3 = > 100 m

(2) See Table 5 for definitions of vegetation and landscape variables.

These findings suggest that, in order to maintain current populations of riparian-associated bird species, riparian woodlands and other natural vegetation should be maintained within at least 100 m on either side of all streams. To restore populations of species that are in decline (e.g., Yellow Warbler) or locally extirpated (e.g., Song Sparrow), the condition of riparian woodlands should be actively enhanced and restored within this zone. The Riparian Bird Conservation Plan (RHJV 2004) lists several recommendations for enhancing riparian habitat for birds and wildlife, which include managing for a diverse understory, increasing the diversity of woody plants, control of invasive plant and animals, and timing of management activities, such as mowing and grazing, to avoid the breeding season. To conserve greater riparian bird diversity, riparian setbacks and activity restrictions should be implemented not only in rural residential and urban areas, but also in agricultural zones.

It is also important to recognize the importance of landscape context in determining habitat suitability for riparian songbirds. The preservation, restoration and linkage of large parcels of undeveloped and uncultivated lands will provide significant benefits to riparian songbird species. Conservation priorities should be large contiguous areas of riparian vegetation surrounded by "natural" uplands to the greatest extent possible. Restoration priorities should be stream segments with large areas of nearby existing riparian habitat.

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Figure B-1. Study Sites

Figure B-2. Central Valley Vegetation

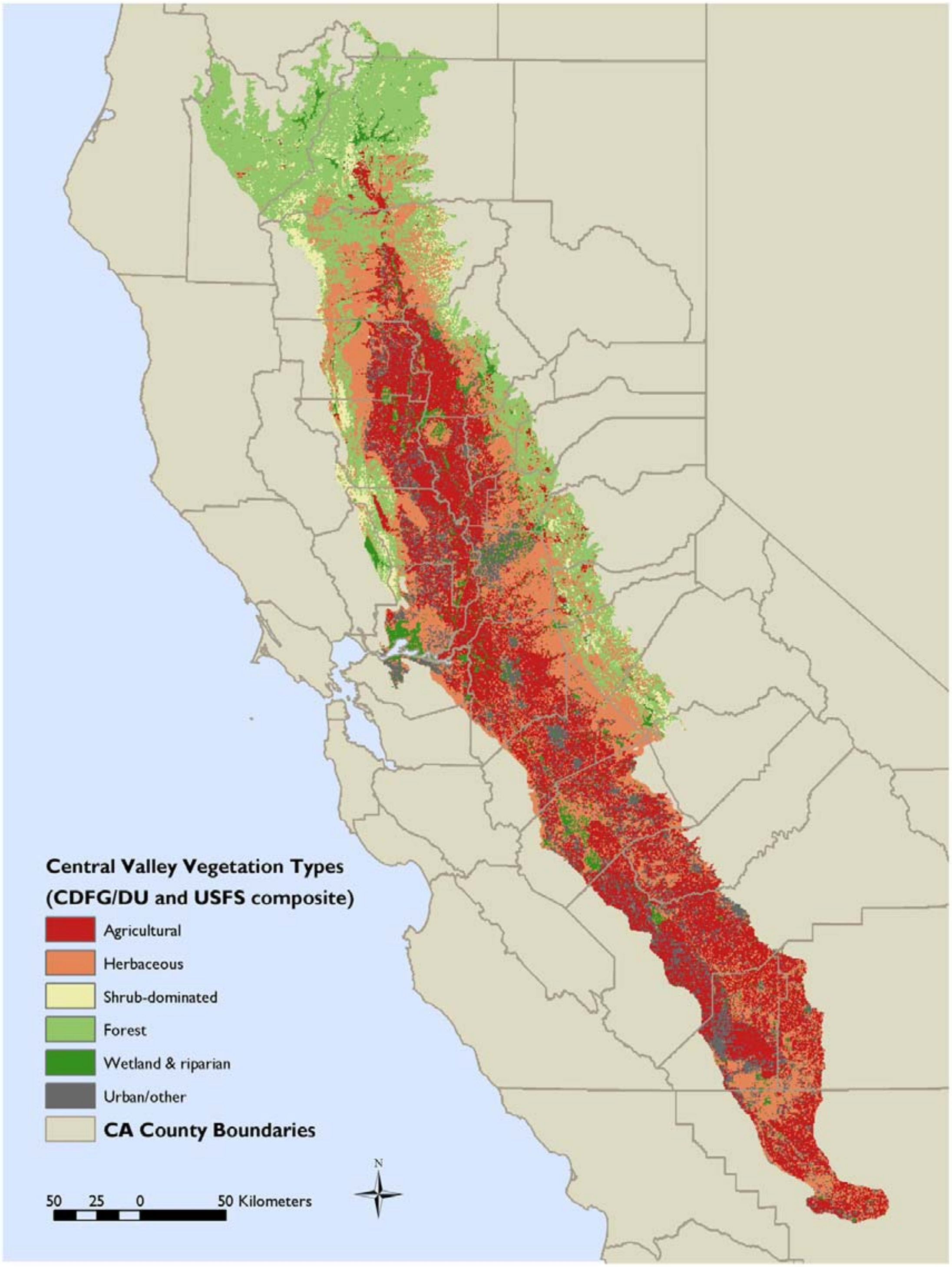

Figure B-3. Central Valley Land Use

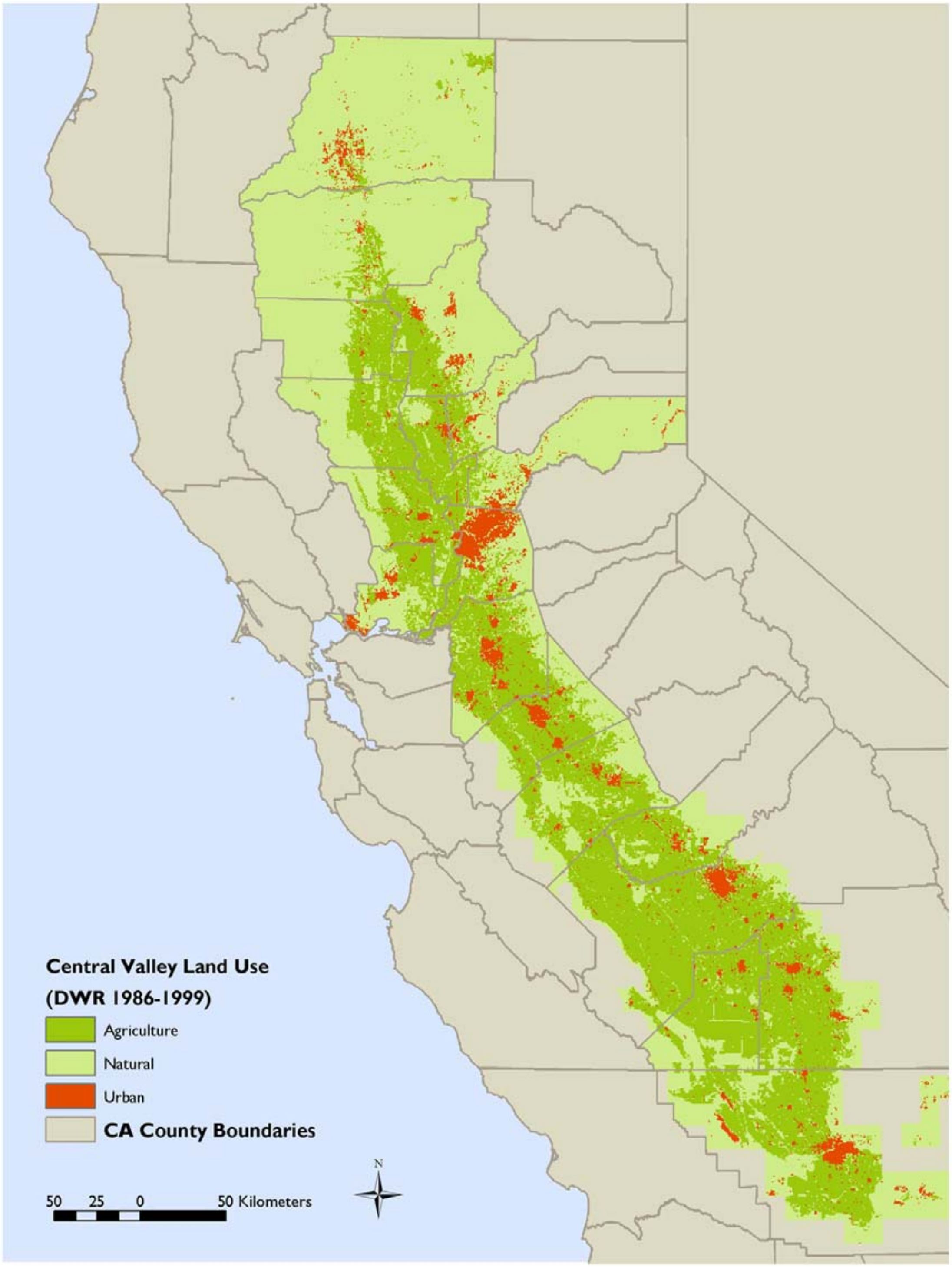

Figure B-4. Mean riparian-associated bird species richness by riparian width category (0-50 m, 50-100 m, >100m) and stream type (mainstem, tributary and wetland). Error bars represent standard errors. Significantly different means are denoted by asterisks (*** = < 0.001)