ENDANGERED PLANT COMMUNITIES OF SOUTHERN CALIFORNIA

PROCEEDINGS OF THE 15th ANNUAL SYMPOSIUM

SOUTHERN CALIFORNIA BOTANISTS

SPECIAL PUBLICATION No. 3

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OF
SOUTHERN CALIFORNIA

PROCEEDINGS OF THE 15th ANNUAL SYMPOSIUM

PRESENTED BY
SOUTHERN CALIFORNIA BOTANISTS
IN ASSOCIATION WITH
DEPARTMENT OF BIOLOGICAL SCIENCES
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Cover: Riparian community on the Santa Ana River below Prado Dam. The proposed All River Plan of the Army Corps of Engineers calls for channelization of this stretch of river, replacing the native vegetation with a concrete-lined ditch. (Photograph by Allan A. Schoenherr)

TABLE OF CONTENTS

INTRODUCTION	
by Dr. Allan A. Schoenherr	1
THE CALIFORNIA VALLEY GRASSLAND	
by Dr. Jon E. Keeley	3
CALIFORNIAN COASTAL SAGE SCRUB: GENERAL CHARACTERISTICS AND CONSIDERATIONS FOR BIOLOGICAL CONSERVATION	
by Dr. John F. O'Leary	24
THE STATUS OF WALNUT FORESTS AND WOODLANDS (<i>Juglans californica</i>) IN SOUTHERN CALIFORNIA	
by Dr. Ronald D. Quinn	42
RECENT RESEARCH ON AND NEW NAMAGEMENT ISSUES FOR SOUTHERN CALIFORNIA ESTUARINE WETLANDS	
by Wayne R. Ferren Jr	55
RIPARIAN WOODLANDS: AN ENDANGERED HABITAT IN SOUTHERN CALIFORNIA	
by Dr. Peter A. Bowler	80
RIPARIAN HABITAT AND BREEDING BIRDS ALONG THE SANTA MARGARITA AND SANTA ANA RIVERS OF SOUTHERN CALIFORNIA	
by Richard Zembal	98

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ENDANGERED PLANT COMMUNITIES OF SOUTHERN CALIFORNIA

Saturday, October 28, 1989
California State University at Fullerton
Room 121, McCarthy Hall

INTRODUCTION

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California is a marvelous place, with a greater range of landforms, a greater variety of habitats, and more kinds of plants and animals than anywhere else in continental North America. There are more endemic plants and animals here than in any area of equivalent size in the United States. When whites first arrived in California, it was a scene of unparalleled, almost unimaginable, natural richness. Unfortunately, this richness coupled with the region's delightful Mediterranean climate soon attracted an unprecedented number of people that encroached upon the landscape to such a degree that California is the state with the greatest number of endangered species.

Nevertheless, California also has the greatest amount of open space in the lower 48 states, and an increasingly devoted proportion of citizens attempting to protect it. These people have won great victories, but many Californians still fail to appreciate the intricate and beautiful natural order of things, and/or that human activities are capable of spoiling it all.

Long-time residents of southern

California have watched as the cow, the plow, and the bulldozer have altered the landscape. We have watched as urban sprawl, like some huge ameba, has gobbled up the native terrain; beaches, wetlands, coastal bluffs, valleys, canyons, and hill-tops. Not only have buildings covered the land, but we have watched developers convert native communities to athletic fields, golf courses, and parklands landscaped with non-native vegetation; all in the name of "open space."

Humans are merely one of the living organisms in the system, but unlike other organisms, they are capable of thinking and analyzing. Those that choose not to think about California's natural treasures have already altered the face of California forever. This symposium is dedicated to all those thoughtful people who are willing to devote time and energy to promote the concept of preservation and/or restoration of native landscapes. It is also dedicated to the change in attitude that is essential if future generations are to enjoy and appreciate California's natural beauty and diversity.

KEELEY - VALLEY GRASSLAND

Figure 1. Present and presumed historical distribution of grasslands in California; sites with remnants of the pristine prairie are named (from Barry 1981, with permission of the California Native Plant Society).

THE CALIFORNIA VALLEY GRASSLAND

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INTRODUCTION

Grasslands are distributed throughout California from Oregon to Baja California Norte and from the coast to the desert (Brown 1982) (Figure 1). This review will focus on the dominant formation in cismontane California, a community referred to as Valley Grassland (Munz 1959). Today, Valley Grassland is dominated by non-native annual grasses in genera such as Avena (wild oat), Bromus (brome grass) and Hordeum (barley), and is often referred to as the California annual grassland. On localized sites, native perennial bunchgrasses such as Stipa pulchra (purple needle grass) may dominate and such sites are interpreted to be remnants of the pristine valley grassland.

In northwestern California a floristically distinct formation of the Valley Grassland, known as Coastal Prairie (Munz 1959) or Northern Coastal Grassland (Holland and Keil 1989) is recognized. The dominant grasses include many native perennial bunchgrasses in genera such as Agrostis, Calamagrostis, Danthonia, Deschampsia, Festuca, Koeleria and Poa (Heady et al. 1977). Non-native annuals do not dominate, but on some sites non-native perennials like Anthoxanthum odoratum may colonize the native grassland (Foin and Hektner 1986).

Elevationally, California's grasslands extend from sea level to at least 1500 m. The upper boundary is vague because montane grassland formations are commonly referred to as

meadows; a community which Munz (1959) does not recognize. Holland and Keil (1989) describe the montane meadow as an azonal community; that is, a community restricted not so much to a particular climatic zone but rather controlled by substrate characteristics. They consider poor soil-drainage an over-riding factor in the development of montane meadows and, in contrast to grasslands, meadows often remain green through the summer drought. Floristically, meadows are composed of graminoids; Cyperaceae, Juncaceae, and rhizomatous grasses such as Agropyron (wheat grass). Some bunchgrasses, such as Muhlenbergia rigens, are found in both montane meadows and moister grasslands. Forbs when present, are typically perennials. East of the interior ranges, grasslands are uncommon although native perennial bunchgrasses in genera such as Stipa, Hilaria and Aristida are common in steppe and desert scrub.

Today, Valley Grassland covers nearly 7 million ha or 17% of the state (Huenneke 1989), although other sources list less than half this amount (Jones and Stokes 1987). There is some evidence that extent of the grassland region has not changed since pre-European conditions, although the spatial distribution of grasslands has likely changed substantially (Huenneke 1989). That is, many current grasslands previously may have been dominated by other vegetation types and vice versa. Without question, many former grasslands have been converted to agricultural and urban use (Barry 1972).

The Valley Grassland community occurs in regions characterized by a broad range of climatic conditions. Average January temperatures may range from 5° to 15°C and July temperatures from 15° to 30°C (NOAA 1988). Annual precipitation ranges from approximately 12 cm to over 200 cm, although all sites are characterized by a summer drought of 4-8 months (Heady 1977). Grasslands are well developed on deep, fine-textured soils although they are not restricted to such conditions (Wells 1962, Adams 1964, Heady 1977).

TODAY'S CALIFORNIA ANNUAL GRASSLAND

Today, the California Valley Grassland is dominated by non-native species of European origin, both grasses and associated forbs (Table 1). Whereas the dominant grasses are all exotic species, the forbs may be either exotic or native (Tables 1 and 2). The origin of more than 70% of the non-native species is the Mediterranean region of Europe (Baker 1989). Presumably the very long history of civilization in that area has selected for aggressive ruderal taxa, which were pre-adapted to colonize California grasslands. Most species have propagules highly specialized for animal dispersal.

The composition of annual grasslands varies spatially and temporally, although the most common species are grasses such as Avena barbata, A. fatua, Bromus mollis, B. diandrus and Lolium multiflorum, and forbs such as species of Erodium (Heady 1956, Bartolome 1979). As is typical of many weeds, most have non-dormant seeds and usually there is relatively little seed carry-over from year to year (Evans and Young 1989, Young and Evans 1989). Different seed germination responses to annual variations in temperature and precipitation may

account for much of the year to year variation in the species composition.

Disturbances such as fire and livestock grazing often alter species composition. In some cases, intense grazing or fires may replace non-native annuals with native annuals such as Eremocarpus setigerus, Trichostema lanceolatum, Madia spp., Lotus spp. and Trifolium spp. (Heady 1977, Parsons and Stohlgren 1989). Some of these are quite noxious and become more abundant due to avoidance by grazers. In some cases, allelopathic suppression of competing vegetation may be involved. Trichostema lanceolatum, for example, produces a volatile oil which makes the plant quite redolent; lab assays indicates potential for allelopathic suppression of other plants but this is not borne out in field studies (Heisey and Delwiche 1985).

Invasion of the Pristine Valley Grassland

The story behind the invasion of the pristine California Valley Grassland illustrates how rapidly and thoroughly an exotic flora can dominate another landscape. It is thought that certain of today's naturalized alien species may have become established in California as early as the 16th century when the first Europeans explored our coastline (Heady 1977). Hendry (1931) reported Erodium cicutarium and a few other exotic annuals from adobe bricks used to build the earliest Spanish missions, suggesting these species were already established (at least in the vicinity of the missions) by the late 18th century. It is during this period that most exotic grassland species were probably introduced, and it seems quite likely that many of these taxa were well established in California by the beginning of the 19th century. There is some evidence that invasion of non-native species took place in waves, with Avena

Table 1. Non-native species dominating the modern annual grassland (nomenclature according to Munz 1959 except for Vulpia see Leonard and Gould 1974). See Table 2 for native taxa which often coexist with these taxa.

Species	(Life Form)*	Common Name
Poaceae		
<u>Aira caryophyllea</u>	(A)	hair grass
<u>Avena barbata</u>	(A)	slender wild oat
<u>A. fatua</u>	(A)	wild oat
<u>Bromus omollis</u>	(A)	soft chess
<u>B. rigidus</u>	(A)	ripgut grass
<u>B. rubens</u>	(A)	foxtail chess
<u>B. tectorum</u>	(A)	cheat grass, downy cheat
<u>Hordeum leporinum</u>	(A)	barley
<u>Lolium multiflorum</u>	(A)	Italian rye grass
<u>Schismus barbatus</u>	(A)	
<u>Vulpia dertonensis</u>	(A)	fescue
<u>V. megalura</u>	(A)	foxtail fescue
<u>V. myuros</u>	(A)	fescue
Apiaceae		
<u>Torilis nodosa</u>	(A)	hedge-parsley
Asteraceae		
<u>Centaurea melitensis</u>	(A)	star thistle, tocalote
<u>C. solstitialis</u>	(A)	star thistle, Barnaby's thistle
<u>Hypochoeris glabra</u>	(A)	cat's-ear
<u>Sonchus</u> spp.	(A)	sow-thistle
Brassicaceae		
<u>Brassica</u> spp.	(A)	mustard
<u>Raphanus sativaus</u>	(A)	radish
Caryophyllaceae		
<u>Cerastium viscosum</u>	(A)	
<u>Silene gallica</u>	(A)	
<u>Stellaria arvensis</u>	(A)	chickweed
Fabaceae		
<u>Medicago hispida</u>	(A)	bur-clover
<u>Trifolium</u> spp.	(A)	clover
Geraniaceae		
<u>Erodium botrys</u>	(A)	filaree
<u>E. cicutarium</u>	(A)	filaree
<u>E. moschatum</u>	(A)	filaree

* (A) = annual

spp. and Brasica nigra dominating in the early 19th century but later being reduced by an increased abundance of Bromus spp., Hordeum spp. and Erodium spp. (Burcham 1956).

Most authorities agree that the first half of the 19th century was the period of transition between native-dominated grasslands and non-native dominated grasslands (Burcham 1957, Dasmann 1966). This was a period of intensive cattle and sheep grazing and was marked by years of severe drought. The first of these in southern California occurred between 1828 and 1830, when no rain fell for 22 months. By 1840, species of Avena, Brasica and Erodium were already abundant in the Central Valley (Dasmann 1966, Wester 1981). In the following decades both cattle and sheep grazing intensified, partly to supply the demands of the increasing gold-rush generated population. Cattle numbers in California rose from approximately a quarter million in 1850 to 1.2 million (Burcham 1957, or 3 million according to Dasmann 1966) by 1860. Between 1862 and 1864 the state was again struck with two severe drought years. Livestock reportedly consumed all available forage and then died en masse, leaving only about half a million cattle by 1870.

This report by one early traveler, William Brewer, while crossing the coast range in 1863, provides some insight into the extent of destruction (Dasmann 1966): "Our road lay over the mountains. They are perfectly dry and barren, no grass---here and there a poor gaunt cow is seen, but what she gets to eat is very mysterious...The ride was over the plain, which is utterly bare of herbage. No green thing greets the eye, and clouds of dust fill the air. Here and there are carcasses of cattle, but we see few living ones."

It is hypothesized that the

populations of the native perennial grasses were severely reduced by these conditions, whereas the impact on the non-native annual grasses and forbs was minimal. Several factors were involved but one critical factor is the perennial nature of the native bunchgrasses. Such plants are in a precarious position for survival during extended drought, even without grazing. One effect of grazing was to reduce root growth and thus make the plants more susceptible to drought (Parker 1929). Irresponsible overgrazing during droughts was the coup de grace and persistence was possible only as seed.

Annuals, by their nature, however, are commonly far more prolific seed producers, some of which may persist for more than a year. Once established, annuals represent formidable competitors, making recovery of the native species even more difficult.

Evidence of the mechanisms for replacement of perennials by annuals is documented in several California studies. In one

investigation, a grassland dominated by the native bunchgrasses Stipa pulchra and Aristida hamulosa, had no viable seeds in the soil, rather the seed bank was dominated by associated non-native annuals (Major and Pyott 1966). Other studies indicated that Stipa pulchra seedlings established very poorly in the presence of annual grass seedlings (Robinson 1971, Bartolome and Gemmill 1981). This may be tied to the rapid soil moisture depletion by annual grasses (Hull and Muller 1977) which could occur prior to the late spring peak in S. pulchra growth (Sampson and McCarty 1930). To further exacerbate the recovery of native perennials, species such as S. pulchra and Poa scabrella have slower growth rates, less root biomass, and shallower rooting depths than non-native annual grasses (Jackson and Roy 1985). Examples of

Figure 2. Overgrazed annual grassland within fenced enclosure and "relict" perennial bunchgrasses (*Stipa pulchra* and *Aristida wrightii*) outside of the fence; Warner Valley, San Diego Co.

grazing-induced displacement of native bunchgrasses can still be observed today (Figure 2).

It is curious that these exotic grasses, which have formed extensive annual grasslands in California, do not dominate the landscape in their region of origin, the Mediterranean Basin (Jackson 1985). Stable grasslands are uncommon in the moister portions of that region, although they may dominate in drier parts of the eastern Mediterranean (Blumler 1984). Perhaps what is most unique about California annual grasslands is the

comparative stability of these ecosystems. Few ecosystems in the world are dominated by non-native annuals with relatively little threat of being displaced by perennials.

Apparently the dominance by exotic annual species in California is partly explained by the fact that, relative to much of the Mediterranean Basin, the climate here is more arid. Commonly, the proportion of annuals in a flora increases as aridity increases, and this is true in California (Richerson and Lum 1980). Further, in light of the increasing aridity

in California during the last 10,000 years (Johnson 1977, Heusser 1978), perhaps the invasion of native perennial grasslands by annual species is the culmination of a process which began thousands of years ago. For example, southern California plant communities during the late Pleistocene Epoch (20,000-40,000 years before present) were comparable to those currently found 300 km to the north (Warter 1976). Obviously, the pristine California prairie or grassland existed under a somewhat moister climate, than that of the modern grasslands.

PRISTINE CALIFORNIA VALLEY GRASSLAND

Distribution and composition of California grasslands, prior to the invasion by European annual grasses, is still a matter of some debate. Clements (1934) suggested that the pristine prairie in California had previously been dominated by Stipa pulchra (purple needle grass) (Figure 3). This conclusion was largely based on the observation of nearly pure stands of this native bunchgrass along railway rights-of-way. Clements believed these stands were "relicts" of what dominated the region in previous eras. Heady (1977) stated that: "The pristine California prairie appears to have been little different in distribution from the present-day grasslands, except the areas taken for cultivation... Stipa pulchra, beyond all doubt, dominated the valley grassland." These points, however, are not universally accepted.

Distribution of the Pristine Valley Grassland

Cooper (1922) believed that many "modern" annual grasslands were formerly dominated by chaparral and not formerly part of the pristine prairie. Repeated

burning, often intentionally for the purpose of "type-conversion", was sufficient to eliminate the woody vegetation and replace it with weedy annuals. Cooper (1922) gave numerous examples of former brush-covered sites in northern California, which had been converted to grassland. Bauer (1930) and Wells (1962) also supported the idea that many modern grasslands in coastal California occur on sites formerly occupied by shrub vegetation. Naveh (1967) has suggested that annual grasslands in Israel had a similar origin from degraded shrublands.

Such "type conversion" from woody to herbaceous vegetation, through repeated burning, has been well documented (e.g., Arnold et al. 1951, Zedler et al. 1983). Russell (1983) has found evidence from pollen cores that, following European colonization of Point Reyes, shrubs decreased and grasses increased. However, such a process of land clearing by burning may have begun prior to the arrival of Europeans (Burcham 1960). Timbrook et al. (1982) contended that the Chumash of coastal southern California did frequent burning as a means of encouraging native annual species and collecting the seed for food. Such sites would have been highly susceptible to invasion by the aggressive weedy colonizers.

Historical studies of changes in annual grassland distribution provide further evidence that annual grasses have displaced shrubs on many sites. In the absence of disturbance by fire and grazing, many areas are often recolonized by coastal sage scrub or other woody plants (Woolfolk and Reppert 1963, McBride and Heady 1968, Oberbauer 1978, Hobbs 1983, Freudenberger et al. 1984, Hobbs and Mooney 1986). The rate of invasion, though, may be relatively slow on some sites (White 1966, Davis and Mooney

Figure 3. Stipa pulchra, purple needle grass, by Melanie Keeley.

1985). An example of historical changes in the grassland-shrubland interface is shown in Figure 4.

In contrast to Cooper's contention, Dodge (1975) suggested that, prior to the European invasion, fires were so frequent that vast stretches of coastal California capable of supporting chaparral were covered by grassland. He contended that since the arrival of Europeans, shrublands have invaded and colonized former grasslands. This theory is largely based on the diary of Fray Juan Crispi, a member of the Portola Expedition which, in 1769, traveled from San Diego to San Francisco (Bolton 1927). Crispi made mention of grasslands numerous times throughout the diary and Dodge (1975) pointed out that today, chaparral, not grassland, dominates the route traversed by the Portola party. These conclusions, however, deserve careful scrutiny. Contemporary highways commonly follow historical routes and thus the grass-covered route traveled by Portola has been replaced today, not by chaparral, but by concrete and asphalt. Additionally, as Oberbauer (1978) pointed out, the diary of Fray Juan Crispi is not an unbiased account of the vegetation, as this padre's function was to convince the church to set up missions in the New World. Additionally, many of the grasslands he referred to were undoubtedly lowland marshy sites. This is suggested by countless references to "green pasture" in the months of July and August. In southern California, upland sites dominated by herbaceous plants do not remain green through the summer drought.

In summary, annual grasslands exist today on sites which, prior to invasion by Mediterranean annuals, were brushlands in some instances and native perennial grasslands in other cases. Throughout the coastal and transverse ranges of

southern California, annual grasslands occur on steep, rocky slopes which probably were never dominated by native bunchgrasses (Figure 5). Throughout the state, on more level terrain of heavy clay substrates, annual grasslands likely occupy sites previously held by native grasses. These conclusions are supported by some experimental work. For studies by Robinson (1971) suggest that native bunchgrasses never formed grasslands on nutrient poor rocky soils. On the otherhand, there is evidence to support the claim made by Shreve (1927) that grasslands were an edaphic climax on deeper soils (Wells 1962, Robinson 1971).

Floristic Composition of the Pristine Valley Grassland

In terms of species composition not everyone agrees that all native grasslands were dominated by perennial bunchgrasses. Hoover (1936), Twisselmann (1967) and Wester (1981) contended that the aridity of the San Joaquin Valley favored an annual flora. This notion is supported by early descriptions made by Muir (1883) and later by Rountree (1936). These authors made reference to annual taxa in more than 30 genera, largely the same ones thought to be components of the pristine grassland (see below). Perennials were either geophytes or suffrutescents and, since grasses formed a minor part of this formation, Hoover (1970) suggested that such a formation, still evident today, be called the Interior Herbaceous community.

It is very likely true that many grasslands were dominated by native bunchgrass species, particularly Stipa pulchra (Figure 3). This idea is based on early historical accounts (Clements 1934), presence of micro-fossils (Bartolome et al. 1986) and the widespread distribution of what are considered relict stands of this

Figure 4. Historical and present day vegetation patterns (as of 1980) on a portion of Oat Mountain, Los Angeles Co. (from Freudenberger et al. 1987, with permission of the Southern California Academy of Sciences).

Figure 5. Example of present day grassland distribution in central Coast Range, San Luis Obispo Co. Annual grasslands on deep soils in the valley bottoms probably have replaced perennial bunchgrass vegetation. Grasslands on the slopes are interpreted as former coastal sage scrub sites which have been converted to annual grasslands by repeated disturbance.

species (Figure 1). These stands occur on a diversity of soil types throughout the state (Bartolome 1989).

Such 'relict' stands of Stipa pulchra always contain a sizable component of non-native annual grasses; particularly, species of Avena and Bromus. Studies have shown that simply excluding grazing from a site does not result in a rapid return to dominance by S. pulchra. In the Central Valley, annual grasslands protected from livestock grazing for more than 40 years still lack a native perennial

bunchgrass flora (Heady 1977). On Hastings Reservation in Carmel Valley, White (1967) noted that sites protected from grazing for 27 years had, on average, only 11% coverage by S. pulchra, comparable to that on grazed sites. Bartolome and Gemmill (1981) report similar findings for sites free of grazing for 20 years at Hopland Field Station in northern California. Other studies have also shown complete protection from grazing does not markedly increase dominance by S. pulchra. In

some cases total exclusion of grazing may favor some non-natives over S. pulchra (Goode 1981).

A study by Bartolome and Gemmill (1981) provides one explanation for the failure of native species to increase upon the cessation of grazing. They reported that S. pulchra establishes seedlings most readily on bare ground but poorly under a cover of litter, a situation typical of an undisturbed grassland. They suggested that one should expect a "climax" species to recruit seedlings without disturbance and therefore this species probably was not the dominant grassland species of the pristine prairie. Their assumption as to the conditions under which a climax grassland species should reproduce, needs to be evaluated carefully.

Although very few studies anywhere in the world have focused on reproduction of perennial grassland species, the little data that are available suggests that reproduction is likely to be tied to fires. Most perennial grasslands are relatively closed to seedling recruitment, and perennial species not only resprout after fire, but are vigorous flower producers the first season after burning (Keeley 1981, Glenn-Lewin et al. 1990). These tendencies also hold true for Californian bunchgrasses such as Stipa pulchra (Ahmed 1983), Stipa lepida (Keeley and Keeley 1984), and Sitanion hystrix (Young and Miller 1985); although the optimal timing of seedling recruitment in S. pulchra is in the second postfire year (Ahmed 1983). Indians perhaps played a critical role in maintaining these grasslands by frequent burning for the purpose of collecting grass seeds (Bean and Lawton 1973). If fires are important to regeneration, intensive grazing would have an additional negative effect on these species by keeping fuel loads below the level sufficient for fires. Other forms of disturbance may also provide safesites

for seedling establishment. For example, Hobbs and Mooney (1985) suggested that gopher mounds, may be important sites of establishment by native species such as S. pulchra. Additionally, personal observations reveal that S. pulchra readily establish on road cuts.

Consistent with the suggestion by Bartolome and Gemmill (1981), are the observations by McNaughton (1968). He reported that Stipa pulchra accounted for up to 41% of the standing crop production on serpentine soils but was largely excluded on sandstone derived soils which were dominated by Avena fatua and Bromus rigidus. Serpentine substrates are low in calcium and high in magnesium, and these conditions result in low productivity compared to grasslands on other substrates. In McNaughton's study, species diversity was much greater on the more open S. pulchra dominated site and was largely due to native annuals. Others have also noted an increase in the balance between Stipa pulchra and non-native annuals as site productivity goes down (Blumler 1984, Huenneke et al. 1990).

There is some reason to believe that grasslands seldom had more than two-thirds coverage by S. pulchra (Biswell 1956, Burcham 1957, Oberbauer 1978, Goode 1981). Today, S. pulchra stands are never completely dominated by this species and often 60% is the greatest coverage one encounters. Thus, it seems likely that the pristine prairie was a mixture of perennial bunchgrasses and forbs. Based on the present occurrences and historical records, associated native species that comprised the pristine grassland are listed in Table 2. A typical stand may have had 50-75% coverage by S. pulchra and other bunchgrasses. The interstitial spaces between grasses were likely occupied by annual forbs and geophytes of the Liliaceae and Amaryllidaceae. Annual grasses were

Table 2. Native species thought to be important components of the pristine grassland of California (nomenclature according to Munz 1959). Based on literature cited in text.

Species	(Life Form)*	Common Name
Poaceae		
<u>Aristida</u> spp.	(P)	triple-awned grass
<u>Danthonia californica</u>	(P)	California oat grass
<u>Elymus glaucus</u>	(P)	blue rye grass
<u>E. triticoides</u>	(P)	creeping rye grass
<u>Festuca idahoensis</u>	(P)	fescue
<u>Koeleria cristata</u>	(P)	June grass
<u>Melica californica</u>	(P)	California melic
<u>M. imperfecta</u>	(P)	small-flowered melic
<u>Muhlenbergia rigens</u>	(P)	deer grass
<u>Poa scabrella</u>	(P)	pine blue grass
<u>Sitanion hystrix</u>	(P)	squirreltail
<u>Sitanion jubatum</u>	(P)	squirreltail
<u>Stipa cernua</u>	(P)	nodding needle grass
<u>S. lepida</u>	(P)	foothill needle grass
<u>S. pulchra</u>	(P)	purple needle grass
Amaryllidaceae		
<u>Allium</u> spp.	(P)	wild onion
<u>Bloomeria</u> spp.	(P)	golden-stars
<u>Brodiaea</u> spp.	(P)	brodiaea
<u>Muilla</u> spp.	(P)	
Liliaceae		
<u>Calochortus</u> spp.	(P)	mariposa lily
<u>Fritillaria</u> spp.	(P)	chocolate lily
Apiaceae		
<u>Lomatium</u> spp.	(P)	
<u>Sanicula</u> spp.	(P)	snakeroot
Asteraceae		
<u>Baeria chrysostoma</u>	(A)	goldfields
<u>Calycadenia</u> spp.	(A)	rosinweed
<u>Chaenactis</u> spp.	(A)	
<u>Hemizonia</u> spp.	(A)	tarweed
<u>Holocarpha</u> spp.	(A)	tarweed
<u>Lasthenia</u> spp.	(A)	
<u>Layia</u> spp.	(A)	tidy-tips
<u>Madia</u> spp.	(A)	tarweed
<u>Malacothrix</u> spp.	(A)	
<u>Microseris</u> spp.	(A)	
<u>Stylocline</u> spp.	(A)	

Boraginaceae

Table 2 (continued)

<u>Amsinkia</u> spp.	(A)	fiddle-neck
<u>Crythantha</u> spp.	(A)	
<u>Plagiobothrys</u> spp.	(A)	
Brassicaceae		
<u>Streptanthus</u> spp.	(A)	
Euphorbiaceae		
<u>Eremocarpus setigerus</u>	(A)	turkey-mullein, doveweed
Fabaceae		
<u>Astragalus</u> spp.	(A)	locoweed
<u>Lotus</u> spp.	(A)	bird's-foot-trefoil
<u>Lupinus</u> spp.	(A)	lupine
<u>Trifolium</u> spp.	(A)	clover
Lamiaceae		
<u>Salvia columbariae</u>	(A)	chia
<u>Trichostema lanceolatum</u>	(A)	vinegar weed
Malvaceae		
<u>Sidalcea malvaeflora</u>	(P)	checker
Onagraceae		
<u>Clarkia</u> spp.	(A)	farewell-to-spring
<u>Camissonia</u> spp.	(A)	smilie-flower
Papaveraceae		
<u>Eschscholzia</u> spp.	(A,P)	California poppy
<u>Platystemon californicus</u>	(A)	cream-cups
Plantaginaceae		
<u>Plantago</u> spp.	(A)	plantain
Polemoniaceae		
<u>Gilia</u> spp.	(A)	gilia
<u>Linanthus</u> spp.	(A)	
Polygonaceae		
<u>Chorizanthe</u> spp.	(A)	
<u>Eriogonum</u> spp.	(A,P)	wild buckwheat
Portulacaceae		
<u>Calandrinia</u> spp.	(A)	
<u>Capmontia</u> spp.	*(A)	miner's lettuce
Ranunculaceae		
<u>Delphinium</u> spp.	(P)	larkspur
<u>Ranunculus</u> spp.	(P)	butter-cups
Scrophulariaceae		
<u>Collinsia</u> spp.	(A)	Chinese-houses
<u>Orthocarpus</u> spp.	(A)	owl's-clover

* (A) = annual, (P) = perennial.

probably never very important in the pristine grassland (Crampton 1974).

Differences in community composition of the pristine grassland have been noted by Beetle (1947) and Crampton (1974). On the drier soils of valleys and slopes, Stipa pulchra would have coexisted with other perennial bunchgrasses such as S. cernua, Poa scabrella, Elymus glaucus, Melica californica, M. imperfecta, Bromus carinatus, Koeleria cristata and Danthonia californica. On rich alluvial soils, Central Valley grasslands were dominated by both bunchgrasses and rhizomatous perennials; including species such as Elymus triticoides, Agropyron trachycaulum, A. subsecundum, Hordeum brachyantherum, Muhlenbergia rigens, Calamagrostis rubescens and Sphenopholis obtusata.

Substrate characteristics may also influence composition of the grassland community. On alkaline flats the above taxa are replaced by the rhizomatous perennial Distichlis spicata and the bunchgrass Sporobolus airoides, plus several annuals specialized to alkaline sites. On gravelly ridges and serpentine soils, Sitanion jubatum is common. Depressions, underlain by an impervious hardpan soil, support a completely different flora. These vernal pool communities are dominated by native annual grasses and forbs adapted to a temporary aquatic environment (Holland and Jain 1977). These azonal communities support a rich endemic flora and non-natives have not successfully invaded most vernal pool communities. This is due to the fact that most non-native grassland species germinate in cool weather, when the pools are filled. Higher temperatures later in the season, when the standing water has evaporated, may preclude grassland establishment. In years of very low rainfall, when the pools

fail to fill with water, grassland species may dominate to the center of the pool basin (Keeley personal observations).

In the coastal foothills, certain grasses, such as Stipa lepida, S. coronata, Elymus condensatus and Agrostis diegoensis, become important. All of these, however, also occur in close association with coastal sage scrub and chaparral vegetation and may never have been components of true grasslands (Keeley and Keeley 1984, Goode 1981, Keeley personal observations). Towards the interior of the state, species of Aristida, Bouteloua, Stipa comata, S. speciosa, Oryzopsis hymenoides and Hilaria rigida dominate.

Biogeography

Native grassland taxa such as Stipa, Elymus, Festuca and Poa are considered to have affinities with cool-temperate regions and are most similar to the flora making up the Palouse Prairie of eastern Oregon and Washington (Sims 1988). Both of these regions are affected by the mediterranean climate of winter rains and summer droughts, which has selected for growth restricted to the cool season. This behavior is so strongly ingrained in the genome of these taxa that artificial watering during the summer cannot prevent dormancy in Stipa pulchra and some others (Laude 1953).

Summer drought may account for the successful invasion by non-native annual grasses in both central California and eastern Oregon. Grasslands which dominate the Great Plains have summer rainfall and annuals have not successfully colonized these prairies (Sims 1988). However, other factors may be involved; the sod-forming (rhizomatous) nature of grasses in the Great Plains may resist invasion better than the bunchgrass life form which dominate grassland of the

Pacific states. Some have suggested that the Great Plains were adapted to more intensive grazing by bison and that the California grasslands had evolved under a regime of weak grazing by deer and antelope (Clark 1956, but c.f. Berry 1972). However, examination of the highly diverse Pleistocene fauna exhibited at the L.A. County Paige Museum, which houses fossils removed from the southern California La Brea Tar Pits, should be sufficient to convince one that this conclusion deserves further scrutiny (see also Wagner 1989).

PRESERVATION OF THE REMAINING PRISTINE VALLEY GRASSLAND

Nearly a fifth of the State was once covered by perennial grasslands, yet today only 0.1% of those remain (Barry 1972). Of the existing grasslands in California, less than 1% are protected within federal, state or private preserves (Jones and Stokes 1987). The California Natural Diversity Data Base has identified Purple Needle Grass Grassland as a community which needs priority monitoring and restoration efforts. Communities with 10% or greater overall cover of S. pulchra constitute significant communities that require special protection as remnants of the once widespread pristine California prairie. In all cases, native perennial grasses coexist with non-native weedy annuals. Some consider these exotic grasses to be a permanent part of our landscape and perhaps best viewed as "residents" (Kay et al. 1981) or "new natives" (Heady 1977). Attempts to eliminate these non-natives have been unsuccessful. However, some restoration treatments appear to have potential for increasing the balance of natives to non-natives.

Evidence suggests that perennial

bunchgrasses are well adapted to frequent burning (Clements 1934, Wells 1962). Some authors have reported that burning will favor native bunchgrasses over non-native annuals (McClaran 1981, Ahmed 1983). However, other studies have reported no increase in Stipa pulchra following burning (Garcia and Lathrop 1984) or a decrease in density of Muhlenbergia rigens under some burning regimes (Lathrop and Martin 1982). Clearly much more research is needed in this area. In light of the differences in phenology and life history between perennial bunchgrasses and annuals, it would be instructive to know how burning in different seasons affects the ratio of natives to non-natives. Since the annual grasses reach reproductive maturity as much as a month earlier than the perennial bunchgrasses (Jackson and Roy 1986), precise timing may alter the balance of reproductive success between these two components.

There is evidence that seeding of Stipa pulchra may be an effective means of increasing the importance of this species on disturbed sites (Rogers 1981, Garcia and Lathrop 1984). Others (e.g., Kay et al. 1981), however, have reported that seeding with S. pulchra does not result in a density sufficient to make this a useful plant for restoration projects. However, since bunchgrasses did not occur in monocultures in the pristine prairie, perhaps, a mixture of native perennials and annuals would be successful.

The observation by McNaughton (cited above), of an inverse relationship between site productivity and dominance by Stipa pulchra, suggests that fertilizing may not enhance restoration of bunchgrasses. This observation also would be supported by experiments of Garcia and Lathrop (1984) which showed that fertilization enhanced the production

of annual grasses far more than the production of S. pulchra. Huenneke et al. (1990) found that fertilizing with nitrogen and phosphorous significantly increased the growth of non-native annual grasses on sites with S. pulchra.

SOUTHERN CALIFORNIA SITES WITH PRISTINE VALLEY GRASSLAND

Figure 1 illustrates extant native grasslands in the state. The following areas in southern California have sizable populations of Stipa pulchra and/or other native bunchgrasses and are interpreted to be fragments of the pristine prairie (Oberbauer 1978, Goode 1981, Barry 1981, Howard 1981, Keeley personal observations). Some of these sites have excellent assemblages of native annual forbs which often generate spectacular spring colors. All sites have substantial non-native cover.

1. Cuyamaca Rancho (eastern San Diego Co.)
2. Santa Ysabel Valley (eastern San Diego Co.)
3. Warner Valley (eastern San Diego Co.)
4. Palomar Mountain State Park (eastern San Diego Co.)
5. San Onofre State Beach and other parts of surrounding Camp Pendleton (western San Diego Co.)
6. Santa Rosa Plateau, Nature Conservancy Preserve and surrounding areas still undeveloped (western Riverside Co.)
7. La Jolla Valley and other sites in Malibu Creek, Pt. Mugu and Leo Carrillo State Parks (western Ventura Co.)
8. Antelope Valley Poppy Preserve (northern Los Angeles Co.)
9. Hungry Valley State Recreation Area (northern Los Angeles Co.)

CONCLUSIONS

California grasslands are dominated on most sites by non-native annual species. These taxa invaded and became established on brush covered sites following repeated burning and on native perennial bunchgrass sites following drought and overgrazing. Pockets of the pristine perennial bunchgrass prairie are extant on disjunct sites throughout the state, and are in need of protection. Much more research will be needed before restoration techniques capable of returning non-native grasslands to their former type will be readily available.

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CALIFORNIAN COASTAL SAGE SCRUB: GENERAL CHARACTERISTICS AND CONSIDERATIONS FOR BIOLOGICAL CONSERVATION

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INTRODUCTION

Coastal sage scrub and chaparral comprise the two major shrubland types that occur in mediterranean-climate areas of cismontane California. Sage scrub is sometimes called "soft chaparral," and it commonly co-occurs with "hard chaparral," the more widespread and better understood type that usually occupies higher, moister sites. Sage scrub ranges in elevation from sea level to 600 m in more inland, southerly portions of its distribution. However, patches of coastal sage scrub may replace chaparral on xeric sites underlain by shallow soils, on argillaceous soils, on road cuts, or in areas subjected to chronic disturbance by burning or grazing (Bradbury, 1978; Kirkpatrick and Hutchinson, 1980; Westman, 1981b; Zedler et al., 1983). Sage scrub extends latitudinally from the San Francisco Bay region southward to El Rosario in Baja California. Within this latitudinal range it occurs on coastal plains and foothills of the Transverse and Peninsular Ranges of southern California and Sierra San Pedro Martir in Baja California, and offshore to the Channel Islands and islands adjacent to northern Baja California.

Unlike evergreen sclerophyllous chaparral, however, sage scrub is characterized by malacophyllous subshrubs

whose leaves abscise during summer drought and are replaced by a lesser number of smaller leaves (Westman, 1981c; Gray and Schlesinger, 1983). During cool spring periods with sufficient moisture, high transpiration and carbon-assimilation rates allow for rapid growth, flowering, and fruiting (Harrison et al., 1971). Most of the dominant species are drought evaders by virtue of their facultatively-deciduous habit, and are thus better adapted to prolonged summer-fall drought in areas of lower rainfall. Sage scrub also contrasts with chaparral in being lower statured (0.5 - 1.5 m vs. 2 - 3 m for chaparral), having shallower root systems, different component species, and comparatively open canopies. The more-open nature of coastal sage scrub permits the occurrence of a greater herbaceous component of forbs, grasses, and succulents than is usually associated with dense stands of mature chaparral. Evergreen sclerophyllous shrubs such as *Malosma laurina*, *Rhus integrifolia*, and *Rhus ovata* are often patchily distributed throughout.

GENERAL CHARACTERISTICS

Floristic Associations

Several associations of coastal sage scrub have been recognized, based upon

its floristic composition throughout its geographic range (Axelrod, 1978; Kirkpatrick and Hutchinson, 1977; Westman, 1983b). As a result of the numerical classification and ordination of 99 samples of the xeric shrublands extending from San Francisco to El Rosario, Mexico, Westman (1983b) confirmed the existence of two distinct plant formations--coastal sage scrub and coastal succulent scrub. The latter formation, earlier recognized by Mooney and Harrison (1972) as coastal sage succulent scrub, occurs along the more xeric end of an evapotranspirative gradient encountered southward from San Francisco to El Rosario. Two floristic associations, Martirian and Vizcainan, are recognized within coastal succulent scrub and are dominated by various succulents in the Cactaceae and Crassulaceae and by completely deciduous shrub species. Four floristic associations within coastal sage scrub are recognized: Diablan, Venturan, Riversidian, and Diegan. These associations occur in reasonably distinct geographical areas along the coastline, with the Riversidian association occupying a more-inland location characterized by higher evapotranspirative stress during summer (Figure 1). The Venturan association can be further subdivided floristically into two subassociations, Venturan I and Venturan II, whose occurrence appears to be controlled primarily by slope aspect and substrate (Figure 2) (Westman, 1983b; Malanson, 1984a). Characteristic species of coastal sage associations are California sagebrush (*Artemisia californica*), several species of sage (*Salvia mellifera*, *Salvia leucophylla*, and *Salvia apiana*), *Encelia californica*, California buckwheat (*Eriogonum fasciculatum*), and *Eriogonum cinereum*.

Postburn Reproduction Characteristics

Similar to chaparral and other mediterranean-type shrub communities, coastal sage scrub is subject to fire and has evolved to accommodate periodic burning. Sage scrub's resilience to periodic wildfire is not completely understood, but seems to be a product of the reproductive strategies of component species and of the nature of the fire regime (Malanson, 1985a). Sage scrub appears intermediate between grassland and chaparral in its resilience to frequent fires (Westman, 1982; Keeley and Keeley, 1988). Fire occurrence intervals of 5-10 years may result in chaparral replacement by sage scrub; while more-frequent burning will likely eliminate sage scrub, leading to site domination by nonnative grasses (Wells, 1962; Kirkpatrick and Hutchinson, 1980; Keeley, 1981; Malanson, 1984b).

Keeley and Zedler (1978) and Keeley (1986) characterized sprouting and non-sprouting as two ends of a regeneration-strategy continuum for chaparral shrubs, many of which reproduce almost exclusively by one means or another (obligate seeders vs. obligate resprouters). Coastal sage shrubs, like several chaparral shrubs, occur at an intermediate location on this continuum. While vigorous resprouting of Venturan sage species may occur after fire, seedling establishment from prefire seed caches is relatively unimportant (Malanson and O'Leary, 1982; Keeley and Keeley, 1984). Resprouting sage species flower vigorously the first few postburn years, thereby providing nonrefractory seeds that germinate in the subsequent years. Consequently, sites of sage scrub are typically mixed-aged (Westman, 1981a).

Figure 1. Geographic extent of xeric Mediterranean-climate shrubland associations based upon Westman's numerical classification (TWINSPAN) of his 99 sites. Reprinted from Westman (1983b) with permission of Kluwer Academic Publishers.

In addition, dominant shrub species are capable of resprouting on a continuous basis in the absence of fire, thus becoming populations of mixed-age branches that assist in survival during long fire-free periods (Malanson and Westman, 1985). In contrast, inland sites of Riversidian sage scrub exhibited little or no postburn resprouting, probably due to having experienced more intense wildfires and intrageneric variation in sprouting vigor (Westman and O'Leary, 1986). Grazing and air pollution have probably also played a role in diminishing populations of resprouters in the Riverside Basin (O'Leary and Westman, 1988).

A profuse cover of herbaceous vegetation usually dominates the sage scrub landscape during the first few postburn years. The bulk of this cover is attributable to specialized fire annuals, most species of which are also found in postburn chaparral (Westman, 1979b; Keeley and Keeley, 1984; O'Leary, 1988). Fire annuals are believed to arise from a dormant seed pool whose germination requires the stimulation of heat, charred wood, and light in varying combinations (Keeley, 1984; Keeley and Keeley, 1987; Keeley et al., 1985), and are typically rare in mature plots of sage scrub (O'Leary, 1990). Resprouting perennial grasses and forbs eventually assume greater areal extent due to subsequent seeding in.

Patterns of Species Diversity

Westman (1981b, 1983b) noted geographic patterns in species richness (numbers of species per unit area) throughout the range of coastal sage scrub based upon 99 0.063-ha sample sites. Mean richness values ranged from 19 (Venturan association) to 30 (Diablan

association) with an overall mean of 24. Variation in site richness was due chiefly to the abundance of herb species. Proportional abundance of herb species declined gradually from north to south, with 80% of the Diablan association being herbs, 66% Venturan, 67% Riversidian, and 57% Diegan. As in chaparral and other mediterranean-type shrublands, species richness in coastal sage scrub is typically highest the first few postburn years then declines with time (Westman, 1981a; Westman et al., 1981; O'Leary, 1990). Aspect-related differences in richness were insignificant between Venturan I and Venturan II subassociations of coastal sage scrub sampled at two scales during postburn years 1-5 (O'Leary, 1990). Mean richness values at the 1-m² scale ranged from about 7-10 species and from about 31-40 species at the 625-m² sampling scale. On average, nearby mature sites of Venturan II sage were richer at both the 625-m² (33 vs. 24 species) and, especially, at the 1-m² (9.8 vs. 4.8 species) sampling scales. Higher richness, equitability, and cover on mature Venturan II sites is likely associated with the relatively mesic habitats upon which this subassociation type develops.

While richness values at these sampling scales are similar to those reported for chamise chaparral (Naveh and Whittaker, 1979), these California shrubland types are depauperate compared to their mediterranean-climate analogues at either sampling scale (Westman, 1988; O'Leary, in preparation). A variety of historical and biogeographical events specific to each mediterranean-climate region have been invoked to account for intercontinental differences in richness. Ecological factors, such as soil-nutrient status, disturbance regime,

Figure 2. Venturan II subassociation of coastal sage scrub near Leo Carrillo State Park in the Santa Monica Mountains. *Salvia leucophylla* is the dominant subshrub in the foreground.

Figure 3. Removal of coastal sage scrub for a housing project located immediately north of Crystal Cove State Park.

topographic diversity, and competition, merit additional consideration as explanatory causes. Low richness in coastal sage scrub and chaparral is more likely due to historical and biogeographical factors. Axelrod (1978) suggested that while ancestral representatives of sage scrub may have extended back into the Pliocene or possibly the Miocene, they were chiefly restricted to dry sites bordering forests, woodlands and dry tropical scrub. Its emergence as a "zonal" vegetation type did not occur until the middle to late Quaternary and is believed to be a result of several factors including: (1) a summer-dry climate with an effective rainfall too low for forest or woodland; (2) tectonism that created steep slopes too dry for either forest, woodland, or grassland; and (3) mass movement and erosional events that stripped slopes and created xeric sites suitable for invasion by sage scrubs. Axelrod (1978) also contended that coastal sage attained most of its present area since the last glacial retreat (12,000 YBP) due to increased warming and drying of the existing mediterranean climate, and human activities such as overgrazing, fire, and clearing.

CONSIDERATIONS FOR BIOLOGICAL CONSERVATION

Patterns of Displacement

While various Native American groups possibly assisted in the post-glacial spread of coastal sage scrub, European settlement since Mission times has clearly caused its marked reduction. Sage scrub's tendency to occur on relatively fertile lowlands made it particularly vulnerable to

agricultural displacement. Numerous Old World weeds inadvertently introduced during this period became established elements of the Californian flora, particularly in those plant communities disturbed by grazing (Aschmann, 1973). Due to past and present agricultural activities, some of the same weeds presently occur to varying degrees in all associations of sage scrub, especially the Riversidian association (O'Leary and Westman, 1988). While grazing of sage scrub is still widespread, its influence is most heavily felt in the Riversidian association and especially on the inner Channel Islands (Westman, 1983a). Sage displacement as well as heavy disturbance to other insular communities has resulted from 100-200 years of heavy-grazing pressure by feral goats, sheep, and pigs.

California has experienced rapid and sustained population increases during the past century, increasing from 1.4 million in 1890 to nearly 30 million in 1990 (U.S. Department of Commerce). With especially rapid population increases in southern California since World War II, agricultural areas and additional sage scrub became displaced by spreading urbanization (Figure 3). Approximately 60% of the state's population lives in the Los Angeles and San Diego metropolitan areas (Lantis et al., 1989). Estimates of the extent of sage scrub displacement range from 36% (Klopatek et al., 1979; based upon 1967 landuse data) to 85% (Westman, 1981a). In contrast, Klopatek et al. (1979) estimate that about 12% of chaparral and 69% of California steppe vegetation has been displaced. The substantial urban growth experienced in southern California since those estimates coupled with future projections accentuates the imperiled status of sage

scrub. Today, the Santa Monica Mountains National Recreational Area and various military lands, particularly Vandenberg Air Force Base and Camp Pendleton, represent the largest contiguous remainders of sage scrub in southern California. Unfortunately conservation of sage scrub is not a high-ranking priority on these military properties; substantial degradation and displacement has occurred. Land that cannot be developed because the terrain is too steep, and various state, county, and city parks are additional refugia for sage scrub.

Fire Management

Concern during this century by various agencies for watershed management and damage to property led to varied and controversial fire-management policies in southern California (Minnich, 1987). Until recent years, the predominant management strategy in Californian shrublands was that of organized fire suppression. More recently ecologists, resource managers, and fire-control agents have increasingly implemented prescribed burning programs as a strategy for achieving a variety of management goals, especially that of fuel reduction. However, such programs have tended to be implemented without any clear understanding of their long-term ecological effects (Malanson, 1985).

At present, chaparral fire frequency averages once every 20-40 years, although it may have been less frequent before European settlement (Byrne et al., 1977). Lightning is considered the natural ignition source, but in recent decades ignition has been largely anthropogenic.

Natural fire frequency in coastal sage scrub is probably nearer the low end of the aforementioned range due to fewer lightning incidences in lower-elevation coastal areas (Westman, 1982), however, anthropogenic ignitions are more common in those areas (Keeley, 1982). Successful management of coastal sage scrub will necessitate clear identification of management goals and their compatibility with life-history traits of component species as interrelated to the various components of fire regime (*sensu* Grubb and Hopkins, 1986) such as interval, areal extent, intensity, and timing (seasonality). To date, vital information regarding the responses of component species of sage scrub associations is largely lacking. However, useful preliminary insights have been gained for Venturan and Riversidian sage scrub by noting the responses of component species to wildfire intensity. Westman et al. (1981) and Westman and O'Leary (1986) contrasted recovery patterns between sites of Riversidian and Venturan sage scrub that had burned under different burn conditions. They simulated intensity for the various sites--a function of a number of variables including fuel load and weather conditions--by using the FIREMOD model of Albin (1976). Fire intensities could effectively explain the differences in postfire vegetative recovery only after apparent differences in the intrinsic resprouting abilities of the dominant species present before fire were taken into account. The Venturan association sites (located in the Santa Monica Mountains) demonstrated markedly higher resiliences following a fire of moderate intensity than the Riversidian sage sites that burned in fires of comparable or lesser intensity.

Malanson (1984b, 1985b)

developed a numerical simulation model of postburn succession of Venturan sage scrub in the Santa Monica mountains based in part upon mode of reproduction and early establishment of the five dominant shrubs in that area. The model predicts changes in species composition and abundance under various fire intervals involving different fire intensities. It also permits testing of alternative management strategies for prescribed burning of this association. However, much remains to be learned regarding the relationship between life-history traits of component species of other associations and their relationship to fire-regime components. No cogent strategy of fire management can be implemented successfully without such information.

Air Pollution

Most of cismontane southern California has been impacted by chronic air pollution since World War II, largely owing to increased automobile usage by a burgeoning population. Compared to various crop species, relatively little is known about the effects of various air pollutants upon native plant species. On the basis of a statistical analysis, Westman (1979) reported a significant negative correlation between percent foliar cover of native species of coastal sage and the mean annual concentration of oxidants. The variable oxidant concentration was more strongly correlated with percent cover than other habitat variables examined such as community structure, topography, substrate, climate, fire, and grazing history. As Westman (1985b) cautioned, results of that analysis simply suggest the role of oxidants as a possible

causal agent in reducing native plant cover in basins inland of Los Angeles. His hypothesis was further strengthened by ordination results (Westman, 1983b) indicating that sites of sage scrub located in less-polluted areas of the Riversidian association supported higher native cover than those located in more heavily-polluted areas. While such statistical evidence is highly suggestive of air pollution as a causal agent, it obviously does not demonstrate causation.

However, the hypothesis was further strengthened by the results of Westman et al. (1985) and Preston (1986) who demonstrated experimentally that, when other growth factors were controlled, coastal sage species suffered significant damage when exposed to levels of oxidants occurring in the region. They subjected 10 species of sage scrub to ozone levels of 0.1, 0.2, or 0.4 ppm for 40 hours per week for 10 weeks in forced-draft, open-topped fumigation chambers. The results indicated various forms of damage to species, even at the lowest exposure level (Figure 4). In addition, Westman (1985a) noted visual injury symptoms comparable to those reported by Preston in species of coastal sage scrub occurring in more heavily-polluted portions of the Santa Monica Mountains National Recreational Area. Based upon a comparison of field and chamber symptoms, it appeared that both O₃ and SO₂ produced field-injury symptoms. Westman also reported that damage symptoms appeared to be produced at lower concentrations in the field than in the chambers (Westman, 1985a; Westman, 1990a).

Other leaf-chamber studies indicate that chaparral species with sclerophyllous leaves tend to be more resistant to acute

A.

B.

Figure 4. Effects of ozone upon California sage brush (*Artemisia californica*). (a) Control individual after 4 weeks in unpolluted air. (b) Individual subjected to an ozone level of 0.4 ppm for 4 weeks. Photos courtesy of K.P. Preston.

SO₂ injury than coastal sage species with malacophyllous leaves (Winner and Mooney, 1980). The susceptibility of sage species is greater due to their higher leaf conductance rates (Winner and Mooney, 1980; Winner, 1981). Chronic air pollution coupled with a more prolonged grazing history in the inland basins may be acting together to increase non-native herb cover at the expense of native species (O'Leary and Westman, 1988).

Mitigation and Restoration

The term mitigation describes actions intended to offset adverse environmental impacts of a project upon various properties of ecosystems. As such, it occurs in various forms such as: (1) requiring a permit to set aside habitat of a similar type, and (2) creating or restoring a habitat type where one previously existed but was displaced or seriously impacted. A serious limitation of the California Environmental Quality Act (CEQA) has been a major loophole in which CEQA lacked any requirement for agencies to monitor results of decisions and evaluate the effectiveness of their mitigation measures. CEQA was amended in 1989 (AB 3180) to close the monitoring loophole, thereby requiring public agencies to adopt post-impact monitoring and reporting programs each time they approve a project that contains mitigation measures to reduce or avoid significant environmental impacts (Cal. Pub. Res. Code 21081.6). While the new legislation does not contain provisions for enforcement, nor convey any new powers to affected agencies, agencies may enforce conditions of approval through their existing "police power" (e.g., using stop work orders, fines, infraction citations,

etc.). While yet imperfect, the new legislation will provide a much-needed feedback loop confirming the implementation and effectiveness of mitigation measures imposed upon projects.

In some areas of southern California there has been clear concern over the amount of disturbance to and habitat loss of coastal sage scrub that has prompted more stringent mitigation policies. Bowler (1990) reported that in some areas of Orange County, mitigation measures involving both habitat replacement and restoration of coastal sage scrub have been implemented at ratios of development:restoration ranging from 1:1 to 1:3. Clearly, comparably generous mitigation measures will be necessary to preserve sage scrub in other areas of southern California undergoing rapid urbanization.

Both habitat restoration (improving existing conditions of a site) and habitat replacement (creation of new habitat) represent potential mechanisms by which coastal sage scrub may be conserved. Both means are very much in the experimental stage for sage scrub as well as many other vegetation types, and little published documentation of results exist. Hillyard and Black (1987) and Hillyard (1988) reported upon the varying degrees of successful establishment of artificially planted stands of sage scrub in Crystal Cove State Park (Figure 5) and at San Clemente State Park. Future habitat restoration and improvement projects need to include an herbaceous component of both annuals and perennials. Inclusion of this component is vital for maintaining diversity, providing a food source for native herbivores, and aiding in the stabilization of postburn nutrient losses.

Figure 5. Restoration site of coastal sage scrub replanted in spring, 1981 with *Eriogonum fasciculatum*, *Encelia californica*, and *Artemisia californica* on a coastal terrace in Crystal Cove State Park.

Rare or Endangered Species

Continued displacement of coastal sage scrub has resulted in the increased isolation of remnant fragments. *Centrostegia leptoceras* is a native plant species that occurs exclusively in coastal sage scrub and is presently listed as endangered by both the state and federal governments (Smith and Berg, 1988). Other rare species such as *Dudleya parva* may also occur in other plant communities but in extremely localized areas. An appendix lists rare, threatened, and

endangered plant species that occur in coastal sage scrub and associated plant communities.

Westman (1987) noted that nearly half the species found in his 99 sample sites of sage scrub were of rare occurrence, i.e., only occurring in one or two of the sites. Most were herbs, some of which, he suggested, may be part of a regional seed rain over sage scrub and chaparral (Westman, 1979b). If his conjecture is correct, preservation of some rare species in sage scrub would require conservation of a large regional mosaic of

both shrubland types. Westman (1983b, 1987, 1990) further suggested that, at least in the Venturan association, certain dominant subshrubs may be acting as keystone species (*sensu* Paine, 1980), i.e., strongly interacting species whose addition or removal causes significant changes in community structure and function. Decline or removal of some dominant subshrubs might lead to a loss of associated rarer species. To be sure, additional research is needed to substantiate the validity of these conjectures. However, if accurate, the necessity of conserving contiguous stands of sage scrub and chaparral becomes an important consideration.

Degradation and displacement of sage scrub also has resulted in substantial habitat loss for a variety of animal species, particularly birds. Bird species that largely or entirely nest in sage scrub, such as the California Gnatcatcher (*Polioptila californica*), are currently Candidate Species for federal listing as endangered or threatened under the Endangered Species Act of 1973, as amended. It appears likely that others such as the coastal subpopulation of the cactus wren (*Campylorhynchus brunneicapillus*) will additionally become Candidate Species for federal listing (Lawrence Salata, U.S.F.W.S. - personal communication). The orange-throated whiptail (*Cnemidophorus hyperythrus*) and San Diego horned lizard (*Phrynosoma coronatum blainevillei*) are Federal Candidate Species of reptiles that respectively occur largely and partly in sage scrub habitats. Some reduction in mammalian species diversity may result from lack of migration through large urban areas, from increased predation by small predators (e.g., raccoons, skunks,

oppossums, etc.) whose numbers have increased due to the ease with which they adapted to urban habitats and due to reduction of their natural predators (coyotes, bobcats, etc.) (Bowler, 1990). Much remains to be learned about the critical size and spacing of remaining sage scrub islands needed to maintain viable plant and animal populations.

CONCLUDING REMARKS

Unanswered questions remain regarding fundamental properties of, and optimal management strategies for, coastal sage scrub. Sage scrub's imperiled status underscores the critical need for its conservation and understanding. The present decade likely represents an "eleventh-hour" period for it as well as the other endangered plant communities discussed in this volume. While such communities *per se* do not yet enjoy legal protection by the federal government, the need for conservation is urgent. In addition to the biotic considerations outlined above, their preservation will help ensure against loss of valuable watershed and loss of much-needed open space.

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APPENDIX

Rare, threatened, or endangered vascular plants occurring in coastal sage scrub as well as other plant communities in California and elsewhere. Source: CNPS database, as compiled from Smith and Berg (1988).

<u>Status/Species</u>	<u>List</u>	<u>Status</u>	<u>Plant Communities</u>	<u>Counties</u>
ENDANGERED				
<i>Acanthomintha illicifolia</i>	1B	CE/C1	Chprl, CSS, VFGr/ clay soil	SDG, BA
<i>Castilleja grisea</i>	1B	CE/FE	CoScr	SCM
<i>Centrostegia leptoceras</i>	1B	CE/FE	CSS (alluvial fans)	LAX, RIV, SBD
<i>Chorizanthe orcuttiana</i>	1A	CE/C1*	CCFrS, CSS	SDG*
<i>Cordylanthus rigidus</i> ssp. <i>littoralis</i>	1B	CE/C1	CCFrS, Chprl, CmWld, CSS/sandy	MNT, SBA
<i>Dudleya brevifolia</i>	1B	CE/C1	Chprl, CSS (Torrey sandstone)	SDG
<i>Dudleya traskiae</i>	1B	CE/FE	CoScr	SBR
<i>Hemizonia conjugens</i>	1B	CE/C2	CSS	SDG, BA
<i>Hemizonia increscens</i> ssp. <i>villosa</i>	1B	CE/C1	CoScr, VFGrS	SBA
<i>Hemizonia increscens</i> ssp. <i>villosa</i>	1B	CE/C1	CSS, VFGrS	SBA
<i>Lotus argophyllus</i> ssp. <i>adsurgens</i>	1B	CE/C2	CoScr	SCM
<i>Lotus dendroideus</i> var. <i>traskiae</i>	1B	CE/FE	CoScr, VFGrS	SCM
<i>Mahonia nevinii</i>	1B	CE/C1	Chprl, CSS	LAX, RIV, SBD, SDG
<i>Mahonia pinnata</i> ssp. <i>insularis</i>	1B	CE/C2	CCFrS, CmWld, CoScr	ANA, SCZ, SRO
THREATENED				
<i>Allium fimbriatum</i> var. <i>munzii</i>	1B	CT/C1	CSS, VFGrS/ clay soils	RIV
<i>Dudleya stolonifera</i>	1B	CT/C1	Chprl, CSS, CmWld, VFGrS	ORA
<i>Gilia tenuiflora</i> ssp. <i>arenaria</i>	1B	CT/C1	CoDns, CSS (sandy sites)	MNT
RARE				
<i>Eriogonum crocatum</i>	1B	CR/C2	Chprl, CSS, VFGrS, /Conejo volcanics	VEN
<i>Hemizonia minthornii</i>	1B	CR/C2	Chprl, CSS/rock outcrops	LAX, VEN

KEY TO ABBREVIATIONS USED IN APPENDIX:

List

- 1A -Plants presumed extinct in California (* -extinct or extirpated)
- 1B -Plants rare, threatened, or endangered in California and elsewhere

Status

- CE -State listed, endangered
- C1 -Enough data are on file to support the federal listing
- C2 -Threat and/or distribution data are insufficient to support federal listing
- CT -State listed, threatened
- CR -State listed, rare
- FE -Federally listed, endangered

Plant Communities

- CSS -Coastal sage scrub
- Chprl -Chaparral
- VFGGr -Valley and foothill grassland
- CCFrS -Closed-cone coniferous forest
- CmWld -Cismontane woodland
- CoDns -Coastal Dunes

Counties and Elsewhere

- BA -Baja California
- LAX -Los Angeles
- ORA -Orange
- MNT -Monterey
- RIV -Riverside
- SDG -San Diego
- SBD -San Bernardino
- SBA -Santa Barbara
- VEN -Ventura
- ANA -Anacapa Isl. (VEN. Co.)
- SCM -San Clemente Isl. (LAX Co.)
- SCZ -Santa Cruz Isl. (SBA Co.)
- SRO -Santa Rosa Isl. (SBA Co.)

THE STATUS OF WALNUT FORESTS AND WOODLANDS (*Juglans californica*) IN SOUTHERN CALIFORNIA

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INTRODUCTION

Juglandaceae, a plant family of the Northern Hemisphere, contains 8 living genera and approximately 60 species (Manchester and Dilcher, 1982). The genus *Juglans* is represented by 21 species, 18 in the Western Hemisphere, 16 in North America, 5 in the United States, and 2 in the state of California (Manning, 1978). Natural stands of the species occurring in northern California, *Juglans hindsii* Jeps., are located in a few places in the lower Sacramento River drainage. This paper deals only with *Juglans californica* Wats., the walnut tree of southern California.

California walnut forests and woodlands are found only in southern California, with a very limited distribution within that range. All walnut stands are within or near urban areas, and the rapid expansion of metropolitan southern California is further reducing the limited extent of this species. This paper is intended to draw attention to this little-known tree, review the extremely limited literature on the species, and promote its conservation.

DISTRIBUTION

The most extensive stands of *Juglans californica* are found in the foothills around inland valleys of Ventura,

Los Angeles, and northern Orange counties at elevations below 900 meters (Griffin and Critchfield, 1972; Swanson, 1967). The current distribution of walnut-dominated woodlands and forests is limited to the Santa Clarita River drainage in the vicinity of Sulphur Mountain, small stands in the Simi Hills and Santa Susana Mountains, the north slope of the Santa Monica Mountains, the San Jose Hills, Puente Hills, and Chino Hills (Griffin and Critchfield, 1972; Swanson, 1967). Outside of this range in Santa Barbara County, western San Bernardino County, and south to San Diego County, walnuts occur mixed with other species of trees, especially oaks. The best-developed stands are found on steep hillsides with northern exposures, almost exclusively on soils derived from Miocene-Pliocene marine shales (Keeley, in review; Leskinen, 1972). This parent material weathers to deep soils high in clay content, with a high water holding capacity (Pomeroy, 1990). On the campus of California State Polytechnic University the soils beneath walnut forests are a meter deep (Pomeroy 1990). Presumably it is the combination of north slope aspect and soils with unusually high ability to retain moisture which allows this tree to remain physiologically active through the rainless summer.

DESCRIPTION

The walnuts of California were first mentioned by Richard Brindsley Hinds, a botanist with the British exploring ship Sulphur, which entered the lower Sacramento River in 1837 (Jepson, 1910). The California walnut (Figure 1) was named by Sereno Watson in 1875. He described it as growing around San Francisco Bay and southward to Santa Barbara, but gave no type locality (Watson, 1875). Early in this century Willis Linn Jepson (1908) recognized a number of morphological differences between the northern and southern forms of *Juglans*, and concluded from the original description and the specimens Watson had before him that the type locality of those trees must have been southern California. Consequently he distinguished the northern form as the variety *hindsii*. Later Jepson (1917) pointed out that there was a wide gap between the distributions of the southern and northern forms of walnuts. This and other evidence led him to separate the two populations as distinct species, *J. californica* (southern) and *J. hindsii* (northern). Because the tree of southern California retained the species name "californica", it is referred to herein as the California walnut.

The California walnut varies considerably in morphology, according to the age of the tree and site characteristics. In Los Angeles and Orange Counties trees tend to have multiple trunks which grow outward from a ring at the base, giving younger plants the appearance of "V"-shaped shrubs. In an Orange County sample of 50 trees, the mean number of trunks per tree was 4.4,

with a range of 1-17 (Swanson, 1967). On drier sites and locations with thinner soils even older individuals may retain the proportions and stature of a shrub, never growing taller than 4-5 meters. When trees on more mesic sites grow larger, the several trunks and projecting branches tend to arch away from the center with the outermost branches touching the ground, giving the tree as a whole a hemispherical shape (Figure 2). The interior of these large rounded trees can be free of low branches and understory vegetation, thereby providing excellent cover at its center for deer, nesting birds, and other vertebrates.

Near canyon bottoms and in the northern portion of its natural distribution, *J. californica* tends to have fewer trunks, growing to a height of 15 meters and assuming the proportions of an upright tree. In some cases large limbs emerge from a single trunk, curving first upward and then toward the ground.

COMPOSITION OF CALIFORNIA WALNUT WOODLAND

California walnuts can occur singly, in mixtures with other species of trees, and in nearly pure stands. The plant community of which they are a part has been classified as "southern oak woodland" by Munz and Keck (1959), while Griffin (1977) placed it in the "coast live oak phase" of a southern oak woodland. This nomenclature implies that evergreen oaks (*Quercus* spp.) dominate these communities, although Griffin (1977) recognized that the California walnut can be locally dominant. In fact, in stands on many north facing slopes in the Puente and San Jose Hills of Los Angeles County, it is the only tree

Figure 1. Pinnately compound leaves of California walnut, *Juglans californica*. (Photograph by Allan A. Schoenherr)

Figure 2. California walnut woodland in Chino Hills near Los Angeles- Orange County border. Note the shape of the trees with outer branches hanging to the ground. Also note intermixed dark-colored coast live oaks and annual grasses. (Photograph by Allan A. Schoenherr)

present, and attains vegetative cover of 100 percent. In such places it would be accurate and useful to call this plant community a California walnut forest. The California Natural Diversity Data Base uses this name, placing it within the category of broadleaved upland forests.

A vegetation map made 50 years ago of the San Jose Hills of Los Angeles County, located at the edges of the present cities of Pomona, Covina, Walnut, and La Verne, shows an unbroken walnut forest extending for a distance of 5 km (Weislander, 1934). As shown on that map the boundaries of this forest had a highly convoluted and irregular shape. In the complex topography of these hills they were found on north and northeast facing slopes, while other slopes were dominated by annual grasses. This general pattern remains today, although it has been interrupted in many places by subsequent urbanization.

There is considerable variation in the structure and species composition of California walnut woodlands. Near the southern end of its range, in the Puente Hills of Orange County, Swanson (1967) found that trees occurred in a density of 84 per ha, produced a 40% canopy cover, and grew with a small number of coast live oaks (Quercus agrifolia) (Table 1). Near the northern end of the range, on Sulphur Mountain in Ventura County, Swanson (1967) measured a tree density almost four times higher (306/ha), and canopy cover more than twice as great (90%). There he reported that California walnuts grow with Juglans hybrids (J. californica x J. regia), tree-sized Sambucus mexicana, and a few coast live oaks. Despite these differences in openness and associated species of trees, the

importance value of California walnuts was nearly identical in both tree communities (Table 1).

A comparison of understory plants at the Ventura county and Orange county sites studied by Swanson (1967) shows that the introduced Old World grass Avena fatua is most frequent at both places (Table 2). This species and all others listed for the Orange county site are indicators of disturbance, and most of them originated in Eurasia. I attribute the species composition of this understory plant community to cattle grazing, which has been the principal economic activity in the California walnut forests and woodlands of both the Puente and San Jose Hills for the past two centuries. With the exception of the ubiquitous A. fatua and Galium triflorum, the Ventura county site shows no evidence of the botanical changes associated with prolonged disturbance, and it is distinct in this respect from the southern site.

PHENOLOGY

Juglans californica is a winter-deciduous tree. In Los Angeles County I have observed that leaves appear in January or February, with all trees in full leaf by March. Trees on warmer or drier sites develop leaves several weeks earlier than those in cooler, more mesic locations. Leaflets begin to lose their green color in October, and leaf abscission is completed in November or December. Thus the trees are leafless for a period of 2-3 months. Flowering begins about the same time as leaf production, with fruits developing to full size during the spring. By late summer the fruits have fully matured. Fruit abscission

TABLE 1. Characteristics of Juglans californica woodlands. Data from Swanson, 1967.

<u>Variable</u>	<u>Orange County</u>	<u>Ventura County</u>
Trees per hectare	84	306
Importance value	203	192
Canopy cover (%)	40	90
Other tree species	<u>Quercus agrifolia</u>	<u>Juglans</u> hybrids <u>Sambucus mexicana</u> <u>Quercus agrifolia</u>

TABLE 2. Frequency of occurrence of understory plants in Juglans californica woodlands. Data from Swanson, 1967.

<u>Orange County</u>		<u>Ventura County</u>	
<u>Species</u>	<u>Frequency (%)</u>	<u>Species</u>	<u>Frequency (%)</u>
<u>Avena fatua</u>	100	<u>Avenua fatua</u>	100
<u>Eremocarpus setigerus</u>	75	<u>Galium triflorum</u>	95
<u>Galium triflorum</u>	70	<u>Juglans</u> seedlings	60
<u>Brassica rapa sylvestris</u>	35	<u>Stachys bullata</u>	30
<u>Elymus</u> spp.	10	<u>Toxicodendron diversiloba</u>	20
<u>Asclepias fascicularis</u>	5	<u>Ribes speciosum</u>	15
		<u>Osmorhiza brachypoda</u>	5

begins slightly before or at the same time as leaf abscission, but some fruits remain on the tree through the winter.

Mature walnut fruits are actively sought and eaten by both California ground squirrels (*Spermophilus beecheyi* Richardson) and western gray squirrels (*Sciurus griseus* Ord.). They are also edible to humans, with a sweet meat that tastes very like the commercially grown English walnut (*Juglans regia*). The nuts have never been grown commercially, however, because the shell is very thick and the meat is difficult to remove from numerous small chambers within the shell. Even so, the California walnut has found some economic use in agriculture. Its roots are more resistant to New World diseases and more suited to California soils than the roots of the English walnut tree, so commercial walnut trees have been produced by grafting scions of English walnut to root-stock of California walnut (Swanson, 1967). Native walnut has also been planted in urban forestry projects in the western Santa Monica Mountains and elsewhere (Radtke, 1978).

In some years, California walnut seedlings appear in great numbers in the spring. Seedling densities of 2000 per hectare have been measured in Ventura County (Swanson, 1967). Germination rates of 20-50 percent are achieved in cultivation, using standard nursery procedures (R. Walsh, personal communication). In nature, young California walnuts on favorable sites grow quite rapidly. In the San Jose Hills, trees older than 20 to 30 years tend to develop heart rot, with the interior portions of the trunk and older limbs becoming infested with termites, wood-boring beetles, and fungi. As they grow larger, portions of

trees so affected may die or break during winter storms, particularly if they carry heavy burdens of mistletoe on their limbs. Older, multi-trunked trees often have some trunks that are healthy, some with heart rot, and others that are dead. I have observed that when a trunk dies, breaks, or is cut, sprouting will often occur at its base. Thus older trees frequently have collections of trunks of various sizes, ages, and states of vigor.

Because of heart rot it is difficult or impossible to determine the age of most mature trees through counts of annual rings. By use of an increment borer near the base of approximately 30 trees, Swanson (1967) was able successfully to age 10 individuals. Regression analysis of these 10 trees showed a close relationship between trunk diameter and ring number (Figure 3, $r = 0.849$). The oldest tree so measured was 68 years old, with a basal diameter of 35.6 cm (Figure 3). In Swanson's samples the most frequent size classes of trunk diameters at breast height (DBH) were 7.7 - 15.2 cm, and 15.3 - 22.9 cm (Table 3), but trees with basal diameters as large as 140 cm (Ventura County) and 87 cm (Los Angeles County) have been reported (Jepson, 1910). Presumably these unusually large trees were also unusually old. Since trees increase in diameter more slowly as they age, an individual with twice the girth of a 68 year old tree might be several times the age of the smaller tree. Unfortunately we may never know, since most or all of these record-sized individuals are gone.

FIRE ECOLOGY

California walnut woodlands are

Figure 3. Annual growth rings vs trunk diameter of 10 *Juglans californica* trees.

TABLE 3. Size classes of trunks of 50 *Juglans californica* trees in Brea Canyon, Orange County. Data from Swanson, 1967.

<u>DBH (cm)</u>	<u>Percent Total (N = 211)</u>
0 - 7.6	10
7.7 - 15.2	29
15.3 - 22.9	29
23.0 - 30.5	24
> 30.5	8

subject to periodic fires. Because most populations of trees are surrounded by annual grasslands, which extend as an understory beneath the trees, fires of low intensity are possible each summer after the grasses die. The dry grasses provide a highly flammable pathway for summer fires to follow between and beneath the trees. The bark of the trees is thin, and even moderate amounts of heat will kill above ground portions of the plant. The ends of the outer branches often touch the ground, so that approaching fires can spread into the tree canopy easily. Burned trees almost invariably resprout from the base, eventually producing a ring of new trunks growing outward from the fire-killed trunks. Several hundred walnut trees in and around the Voorhis Ecological Reserve of California State Polytechnic University, Pomona were burned in a wildfire in July, 1989. One year after this fire there is no evidence that any of these trees were killed, even though most branches and stems died. Almost all individuals sprouted from the base within 6 weeks of the burn.

Repeated fires are sufficient to explain why most trees have multiple trunks. It may be that the trees of Ventura County have been subjected to fires less frequently. As a whole they have fewer trunks per tree than those of Orange County (Swanson, 1967). Older California walnuts have large woody platforms at the surface of the ground, from which living trunks arise. Some of these platforms are quite large, more than a meter across, presumably increasing in size each time a fire kills living trunks and new ones sprout ever farther from the original center. Thus a ring of trunks may surround a basal platform that is

many times older than any living trunk. Since the platform is largely buried beneath the soil it shields meristematic tissue from the heat of passing fires, and post-fire sprouts arise from its lower portions. I interpret the basal platform as an adaptation to fire, and as evidence of the long existence of California walnuts in the fire environment of southern California. It is similar in form and analogous in function to the lignotuber at the base of many species of chaparral shrubs.

ANIMAL COMMUNITY

Walnut forests and woodlands provide favorable habitat for a number of vertebrates and invertebrates. The rich foliage, present for 9-10 months of the year in a landscape with relatively few trees overall, combined with the many hollow trunks and limb holes produced by heart rot, provides sustenance for many wood- and foliage-feeding invertebrates. The annual leaf fall generates considerable litter, providing another habitat for invertebrates. These animals, in turn, can attract insectivorous vertebrates to the woodland. A two year survey in a walnut woodland in the San Jose hills found 29 species of diurnal birds (C. Shannon, unpublished data). The presence of more than half of these bird species is attributable to the walnut trees. Older walnuts provide numerous nesting cavities for birds and rodents, and the upper reaches of the tallest trees are used as roosts and nesting places for raptors and owls. The hollow bases of old trees are preferred burrow sites for California ground squirrels, and probably for various species of reptiles and

invertebrates as well. The walnut fruits are avidly sought by both California ground squirrels and western gray squirrels. Since some of the walnuts persist on the trees into winter, they are a continuing source of food for the tree squirrels. In areas where both walnut woodlands and collections of introduced trees are present, western gray squirrels forage preferentially in the walnuts. It is very likely that the gray squirrels are an important dispersal agent for walnut seeds. This would be analogous to the eastern woodlands of North America, where there is evidence that the fox squirrel, a species which is ecologically similar to the gray squirrel, has coevolved with *J. nigra*, the black walnut (Stapanian and Smith, 1978).

MANAGEMENT OF WALNUT FORESTS AND WOODLANDS

The distribution of the California walnut described by Jepson (1908, 1917) was limited to a relatively few foothill areas of southern California. The largest trees reported in Los Angeles County were located along Walnut Creek in the eastern San Gabriel Valley (Jepson, 1910). Even before this watercourse was channelized, these trees had apparently vanished (Weislander, 1934). The best remaining stands of these trees south of Ventura County are found in the Puente and San Jose Hills, and these are being rapidly fragmented and destroyed by the rapid urbanization of hillsides in eastern Los Angeles and northern Orange Counties.

One of the most extensive walnut woodlands in the Puente Hills is located in Tonner Canyon. At this writing there

are proposals to remove thousands of walnut trees in the upper part of Tonner Canyon in the Puente Hills of Los Angeles County to construct a golf course, and a second proposal would bulldoze many more in the lower part of the canyon in Orange County for a subdivision. A third proposal suggests the construction of expressways along the full lengths of Tonner and Soquel Canyons (Chang, 1990). Soquel Canyon is also in the Puente Hills, and contains walnut woodlands. In the San Jose Hills the best developed walnut forest in the vicinity of Cal Poly University was destroyed by expansion of a landfill. This rapidly vanishing plant community has received little attention from either the scientific or environmental community. The first and, to my knowledge, only comprehensive study of California walnut woodlands is an unpublished master's thesis completed more than 20 years ago (Swanson, 1967).

Interest in the hardwood tree communities of California has been increasing since the 1970's. This interest, however, is focused almost exclusively on oaks. A detailed vegetation classification system for southern California made no mention of *Juglans*, not even in the species index (Payson, et al, 1980). That same year a symposium on California oaks dealt with other tree species associated with oaks, but not walnuts (Plumb et al, 1980). An introductory paper at a recent symposium on California hardwoods stated that most research continues to focus on oaks, with little attention given to other widespread hardwood species (Conard and Griffin, 1987). A single sentence in the symposium proceedings mentioned the increasing disturbance and rarity of

California walnut woodlands due to human activity (Barbour, 1987). The most recent volume on the hardwoods of California, which includes extensive statistical data on most minor hardwood species, does not discuss Juglans at all, although the genus is listed in the species index (Bolsinger, 1988). In 1987 the Integrated Hardwood Range Management Program was formed, a statewide organization with the goal of creating a program of research, education, and management of California hardwoods (Scott, 1987). It is described as a vehicle for promoting oak conservation. The conference on California hardwoods scheduled for late 1990, like all those that have preceded it, will be concerned almost exclusively with oaks (Standiford, personal communication).

There are 2 problems to be addressed concerning management of California walnut woodlands; 1. the outright disappearance of the community in the face of rapid urbanization, and 2. reversal of ecological changes within the community due to overgrazing, increased fire frequency, and introduced species of understory plants. The first problem is the most important and urgent; if it is not dealt with, the second problem is moot. There are several de facto reserves for California walnut woodlands in the San Jose and Puente Hills. Examples of such reserves are Bonelli Regional County Park, California State Polytechnic University, Mt. San Antonio College, canyon areas of Forest Lawn, and the Firestone Boy Scout Reservation. These places do not have the protection and preservation of walnut woodlands as an explicit management goal, but in the course of their other activities they do

accord incidental (or accidental) protection to the trees. There are two exceptions to this pattern. The first is Mt. San Antonio College, which has established the first and only California walnut reserve on campus agricultural lands. The second is Chino Hills State Park, between Orange and San Bernardino Counties. Walnut trees are not as abundant there as elsewhere, but the park does have the goal of protecting and restoring native plant communities, including walnut woodlands.

It is important to recognize that California walnuts are rapidly approaching the status of a custodial species, which I define as a species with remnant natural populations found only within reserves of limited size, where protection of the population is an explicit management goal. Free ranging herds of American bison (Bison bison) in natural parks are an example of a custodial species. The Engelmann oak (Quercus engelmannii) is another example of a southern California tree that is approaching the status of a custodial species. A major reason for the establishment of the Nature Conservancy's reserve on the Santa Rosa Plateau of Riverside County was the conservation of this species of tree and other rare plant populations. The fact that California walnuts can be grown readily outside their natural range (Swanson, 1967), or regrown on disturbed sites (Leskinen, 1972), does not lessen the importance of protecting natural populations any more than the ease of propagating coast redwoods in urban parks and gardens makes it less important to conserve natural populations on the north coast of California. The genetic composition of natural tree populations is the product of

thousands of generations of natural selection. Such a population is attuned to the site at which it occurs in countless and subtle ways that we are unequipped to understand fully. Moreover, by virtue of their size and longevity, walnut trees provide the framework for an ecosystem containing innumerable species of microorganisms, animals, and other plants. At present we lack the resources to document the presence and understand the importance of all these many life forms, and it is tragically certain that if the trees disappear so too will a host of companion species.

It is encouraging to note that the conservation and propagation of California walnuts is beginning to receive attention. Nurseries in Los Angeles, Orange, and Riverside Counties that specialize in native plants now purchase hundred- pound quantities of California walnut seeds gathered from the wild (R. Walsh, personal communication). Each 100 pounds contains roughly 10,000 seeds. If even a small percentage of these are successfully germinated, potted, and planted, then thousands of walnut seedlings are growing somewhere each spring. Chino Hills State Park plans to use this species in revegetation programs.

Most of the plants in the understory of California walnut forests and woodlands in Los Angeles and Orange Counties are alien species favored by overgrazing, frequent fire, and other disturbances. The ubiquitous Avena fatua (wild oats) and other introduced species dominate the understory of walnut woodlands, almost to the exclusion of the native species they have displaced. It would be desirable within reserves to extirpate alien species from the

understory of California walnuts and to replace them with those native species most likely to have been present prior to arrival of Europeans. The extirpation phase could be quite difficult, and might be practical only on small plots, but when successful, reintroductions of stable associations of native understory species would be possible.

As discussed above, fire plays a role in the ecological structure and function of walnut woodlands, as it does in most californian plant communities. The prehuman (or pre-European) fire frequency is unknown. Fire today is frequent; it is an annual possibility in most locations, where dead annual grasses are present beneath and between the trees during the summer fire season. Fire in the past may have been less frequent, since the original grasses were mostly perennial rather than annual, and would have produced a less flammable summer ground cover. As California walnuts become a custodial species, and therefore subject to a managed fire regime, I suggest that prescribed fires of low intensity, at intervals of several years, be tested for their effects on the walnut community, particularly in places where an understory of native plants has been reestablished.

This paper has reviewed the limited amount of information available about the California walnut. It is my hope that it will help to emphasize the increasingly precarious status of remaining natural populations, and encourage positive action to conserve this element of the natural heritage of southern California. The juggernaut of urban growth is at the doorstep of most of the remaining walnut woodlands. We have

precious few native species of trees, and native stands of this one cannot be allowed to vanish.

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RECENT RESEARCH ON AND NEW MANAGEMENT ISSUES FOR SOUTHERN CALIFORNIA ESTUARINE WETLANDS

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INTRODUCTION

Wetlands are of increasing interest to people from many walks of life, because there is a general increase in knowledge regarding the importance of wetland values, and because of agency and political mandates to protect, restore, and even create new habitat. In California, for example, the Fish and Game Commission has set a goal to achieve a 50% increase in wetland habitat by the year 2000 (California Department of Fish and Game, 1987). This ambitious goal and other local, state, and federal initiatives are crucial, because there exist today only about 9% (ca. 450,000 acres) of California's pre-1900 wetland resources (Dennis, 1984).

Even with such extensive losses, wetlands still form a rich group of habitats in southern California, including five major categories (Cowardin et al., 1979; Ferren, 1988): (1) marine (intertidal ocean shoreline); (2) estuarine (intertidal coastal embayments); (3) riverine (river and stream channels and shorelines); (4) lacustrine (lake); and (5) palustrine (marshes, ponds, forested wetlands, etc.). Many of the habitat examples that still remain, such as palustrine wetlands (e.g., vernal pools, freshwater marshes, and riparian woodlands and forests), have been seriously degraded or endangered as a result of the impacts from agricultural development and urbanization, particularly along the coast.

Some of the most heavily impacted types in southern California are estuarine

wetlands. Estuaries support a complex system of subtidal deepwater habitats and adjacent intertidal wetlands that are generally semi-enclosed by land but have open, partially obstructed, or sporadic access to the ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land (Cowardin et al., 1979). In estuaries where evaporation is high, such as many in southern California (Zedler 1982), the soil and water salinity can reach levels in excess of ocean water (hypersaline), particularly during the summer; whereas in others with perennial runoff, all or portions of the estuaries can be diluted to slightly brackish (oligohaline) or even occasionally to freshwater conditions (Ferren et al., 1990). Cowardin et al. (1979) described the limits of the Estuarine System as extending "... (1) upstream and landward to where ocean-derived salts measure less than 0.5 ppt during the period of average annual low flow; (2) to an imaginary line closing the mouth of a river, bay, or sound; and (3) to the seaward limit of wetland emergents, shrubs, or trees where they are not included in (2) [above]."

In southern California, regulatory agencies such as the U.S. Fish and Wildlife Service (Zedler, 1982), California Department of Fish and Game (1983), and the California Coastal Commission (1989) estimated that 75-90% of coastal salt marsh habitats have been destroyed, and the remaining estuarine habitats often have been degraded seriously. Dennis (1984) estimated that approximately

16,763 acres of wetland remain in coastal southern California. One result of this habitat destruction or degradation has been the endangerment or declining numbers of various endemic estuarine plants, such as salt marsh bird's-beak (*Cordylanthus maritimus* ssp. *maritimus*), and animals such as the light-footed clapper rail (*Rallus longirostris levipes*), Belding's savannah sparrow (*Passerculus sandwichensis beldingi*), and tidewater goby (*Eucyclogobius newberryi*). In spite of (1) the increased public and agency interest, (2) the acknowledged habitat value for sensitive plants and animals, (3) the high aesthetic, open space, and recreational values, and (4) their endangered habitat status in general, researchers have investigated the ecology, natural resource richness, or restoration potential of few southern California estuarine ecosystems.

Two notable exceptions, however, are the extensive contributions of Onuf and Quammen (e.g., Onuf, 1987; Onuf et al., 1979; Onuf and Quammen, 1983, 1990; Quammen 1984), particularly at Mugu Lagoon Estuary, and the Pacific Estuarine Research Laboratory at San Diego State University (e.g., Zedler, 1977, 1982, 1984; Zedler et al., 1980, 1990; Zedler and Beare, 1986; Zedler and Nordby, 1986; Fong et al., 1988; Langis et al., in press; Nordby and Zedler, in press), particularly at Tijuana Estuary.

In this paper, I shall review four research topics or management issues that have been pursued recently at the University of California, Santa Barbara, regarding southern California estuarine wetlands and deepwater habitats. These include: (1) results of an evaluation and classification of estuaries in southern California, including studies at Devereux Slough and the Ventura River; (2) results of research on vegetation and soil salinity patterns at Carpinteria Salt Marsh Reserve; (3) a review of wetland

functional values of various types of estuaries and some of the impacts that have degraded these values; and (4) new estuarine management issues resulting from the potential impacts of an accelerated rise in sea level.

INVENTORY AND CLASSIFICATION OF ESTUARIES

Studies of selected estuaries throughout southern California have provided the opportunity as well as underscored the need to classify these wetlands according to their physical and biological attributes for basic research and management purposes. Although others (e.g., Pritchard, 1967) have presented classification schemes on a broad scale or have discussed types of Pacific Coast estuaries (e.g., Collins, 1990), including fjords (glacier-carved), bar-built, drowned river mouths, and blind estuaries (permanently blocked from the ocean), none has been specific to the many variations of origin, topographic setting, hydrology, and salinity that occur in southern California. Zedler (1982), Zedler and Nordby (1986), and Onuf (1987), however, have compared some of these variations among southern California estuaries to demonstrate similarity or difference among these systems, and have discussed individual estuaries in the context of broader classification schemes.

Results of the past decade of research at UCSB reveal at least four major types of estuaries reflecting their origin, type of watershed, and relationship to the marine environment. These types are: (1) river mouth estuaries with brackish lagoons; (2) canyon mouth estuaries with brackish or euryhaline (fluctuating salinity) lagoons; (3) bay estuaries with extensive deepwater habitats and intertidal wetlands; and (4) structural basin estuaries with steep

watersheds, much sedimentation, and hypersaline conditions. Although the biota of these types of estuaries are often quite distinct and reflect the differences in salinity and tidal regimes characteristic of each type, there is actually a continuum of types of habitats and biotic associations that suggests the inter-relatedness among the types of estuaries. Onuf (1987) attributed the "great variety" of coastal wetlands in southern California to their variation in size, connection with the ocean, and human-caused alterations. This variation is more like a spectrum rather than an artificial grouping of unrelated types. The terminology of wetland classification used herein generally follows that of Cowardin et al. (1979) and Ferren (1989).

River Mouth Estuaries

The river mouth type of estuary is perhaps best exemplified by the Ventura River Estuary (Fig. 1), which covers approximately 30 acres on the western edge of the City of San Buenaventura, and which includes portions of Emma Wood State Beach and Seaside Wilderness Park. The watershed of the Ventura River extends 37 km (23 miles) inland from the ocean, covers approximately 580 km² (226 square miles), and reaches an elevation of 1900 m (6,000 feet). Flood flows have been measured near the estuary at rates from 11,000-58,000 cubic feet per second. Physical characteristics of this estuary include: (1) year-round freshwater runoff and occasional catastrophic flooding and flushing as a result of large winter storms; (2) a cobble and sand bar that separates the ocean from an estuarine lagoon except during periods of flushing, particularly following storms; (3) brackish water conditions throughout the estuary when the mouth is open, but a freshwater or slightly brackish layer on the lagoon

surface when the mouth has been closed by a cobble and sand bar for extended periods, thus temporarily extending the riverine environment into the estuary; and (4) a brackish (mixohaline) lower layer that has reduced levels of dissolved oxygen during periods without flushing (Ferren et al., 1990).

Biotic communities supported by this type of estuarine environment reflect the brackish lagoonal conditions (Ferren et al., 1990). Nonpersistent Estuarine Emergent Wetlands occur on channel beds and bars that are exposed for long periods when the mouth is open, and are dominated by native annual species such as coast goosefoot (*Chenopodium macrospermum* var. *farinosum*), spear-leaved saltbush (*Atriplex patula* ssp. *hastata*), and salt marsh sand spurrey (*Spergularia marina*). Persistent Estuarine Emergent Wetlands occur on channel margins and are dominated by California bulrush (*Scirpus californicus*) and narrow-leaf cattail (*Typha domingensis*). Estuarine Aquatic Bed communities include both a rooted-vascular type dominated by spiral ditchgrass (*Ruppia cirrhosa*) and a floating type dominated by duckweed (*Lemna* spp.), when freshwater or oligohaline (slightly brackish) conditions prevail. Palustrine Forested and Scrub/Shrub Wetlands immediately adjacent to the estuary are dominated by freshwater species such as arroyo willow (*Salix lasiolepis*) and mule fat (*Baccharis salicifolia*) apparently because soils are not permeated by saline or hypersaline water. Occurrence of salt marsh vegetation and organisms is minor due to the prevalent freshwater influence in this ecosystem.

The tidewater goby, a candidate endangered fish, occurs in the lagoon, as do two anadromous fish, steelhead trout (*Oncorhynchus mykiss*) and pacific lamprey (*Lampetra pacifica*). These anadromous fish still spawn upriver in spite of many

impacts (e.g., polluted effluents, dams on tributaries, and flood control structures and activities) that have reduced the importance of the Ventura River for anadromous fish as compared with historical occurrences of the fish (Moore, 1980). In contrast to many southern California estuaries that have check-dams or other artificial structures that separate the estuarine and/or marine systems from the riverine system, the Ventura River has seasonally contiguous habitats. This estuary provides an essential transition between marine and riverine environments and supports habitats for anadromous fish (Ferren et al., 1990). In addition to values for fisheries, many resident and migratory birds use both the flooded lagoon and irregularly exposed channels and bars of the estuary.

Because the watershed of the Ventura River is one of the most rapidly geologically emerging landscapes along the entire Pacific Basin (Lajoie and Sarna-Wojcicki, 1982), erosion is proceeding rapidly in the headwaters. The deposition of coarse alluvial materials at the river mouth helps define the nature of the estuarine environment and adjacent habitats such as the cobble-dominated Marine Wetlands, the Palustrine Forested and Scrub/Shrub Wetlands of the flood plain, and the coastal dunes, which contribute to the overall richness of the ecosystem of the Ventura River Estuary.

Canyon Mouth Estuaries

Emergent portions of the southern California coastline are characterized by a series of incised, parallel canyons, arroyos, and valleys that drain watersheds in mountain, foothill, coastal plain, and coastal mesa landscapes. These "canyons" empty into the ocean through small estuaries that are quite variable in size, frequency of tidal flushing, salinity

regimes, and biota. Two contrasting examples are: (1) Malibu Lagoon in Los Angeles County, which has a large, steep watershed (27,350 ha; 67,000 acres), much rapid seasonal runoff and year-round artificial inflows that generally do not pond in the estuary, frequent flushing by tides, and an overall brackish nature (Manion and Dillingham, 1989); and (2) Devereux Slough in Santa Barbara County, which has a small, low-profile watershed (950 ha; 2330 acres), relatively slow runoff that ponds in the estuary, a euryhaline nature, and only infrequent flushing by tides (Ferren et al., 1987; Davis et al., 1990).

Devereux Slough (Fig. 2) is located within Coal Oil Point Natural Reserve on West Campus of the University of California, Santa Barbara. It recently has been the focus of studies (e.g., Stanley, 1985; Ferren et al., 1987; Davis et al., 1990) by the UCSB Campus Wetlands Management Committee to develop a management plan for the estuary and other campus wetlands. Devereux Slough covers approximately 30 ha (70 acres) and has a coastal terrace and foothill watershed with elevations ranging 3 to 238 m (10 to 575 feet). The predicted average annual runoff is 737 acre feet (Davis et al., 1990).

As with the majority of canyon mouth estuaries, a natural sand (or cobble) barrier separates Devereux Slough from the open ocean most of the year. Following months of dry season evaporation, winter storm runoff fills the main slough area to an elevation usually exceeding 2.3 m (7 feet) above mean sea level (MSL) before the barrier is breached. This level exceeds the elevation of tidal flushing. Breaching occurs between December and April, but in some years may not occur if there is insufficient runoff. After breaching of the mouth barrier, tidal flushing can occur up

to several weeks before the sand bar again blocks a surface connection between the marine and estuarine environments.

Runoff, tidal flushing, and evaporation have a significant impact on the salinity of Devereux Slough. In contrast to river mouth estuaries where runoff generally exceeds evaporation throughout the year, many canyon mouth estuaries (e.g., Devereux Slough) receive virtually no runoff during the dry season; and subsequently, evaporation (and perhaps seepage through the sandbar to the ocean) results in a loss of all water in some of these estuaries except for channels, which may intersect the water table. During summer and fall, surface and bottom water is hypersaline and has been recorded as high as 60-80 ppt (Ferren et al., 1987; Davis et al., 1990). Initial periods of winter runoff reduce surface salinities to brackish conditions (e.g., 6-12 ppt), but stratification occurs with cooler, less saline water occurring over warmer, hypersaline water, especially in channels. Breaching of the mouth barrier usually results in emptying of the estuary and reduction of salinities to as low as 0.0 ppt in runoff water passing through the estuary (Ferren et al., 1987). Subsequent tidal flushing with ocean water produces brackish to marine conditions ranging from 25-35 ppt throughout the well mixed water column (Davis et al., 1990). Although high inter-annual variation characterizes the hydrology of Devereux Slough (Davis et al., 1990), the sequential processes of runoff and ponding, draining and flushing, and evaporation produce the generally annual euryhaline (fluctuating salinity) regimes that often characterize this type of estuary.

The dynamic physical environment at Devereux Slough has a major role in determining the distribution and composition of the biotic communities. Salt marsh vegetation dominated by

pickleweed (*Salicornia virginica*), alkali heath (*Frankenia salina*), and coastal saltgrass (*Distichlis spicata* ssp. *spicata*) occurs on the margin of the estuary; however, because of prolonged periods of flooding that prevents colonization by emergent salt marsh species, only small islands in the main slough area are vegetated by emergent plants, particularly pickleweed. Shallow channels and channel margins occasionally support small colonies of prairie bulrush (*Scirpus maritimus*). Most of the broad, seasonally exposed mudflats are colonized by a large population of ditchgrass (*Ruppia maritima*) (Ferren et al., 1987), a submerged rooted vascular species. This is in contrast to river mouth estuaries (e.g., Ventura River) and some canyon mouths with perennial sources of fresh water (e.g., San Antonio Creek in northern Santa Barbara County), which often support spiral ditchgrass (*Ruppia cirrhosa*) and fennel pondweed (*Potamogeton pectinatus*) that are regionally characteristic of ponded or seasonally ponded brackish or alkaline systems.

Because surface waters during ponded conditions are generally only slightly brackish, brackish marsh vegetation occurs in scattered areas on the margin of the estuary at higher elevations than the salt marsh vegetation (Ferren et al., 1987). This is particularly true in an area of the estuary near the mouth that extends into a dune swale (Fig. 3), which is dominated by California bulrush (*Scirpus californicus*). A wetland terrace between the main slough channel and dune swale provides habitat for other brackish marsh species such as coast goosefoot (*Chenopodium macrospermum* var. *farinosum*) and salt marsh bulrush (*Scirpus robustus*), and the rare occurrence of tall stephanomeria (*Stephanomeria elata*), which reaches the southern limit of its range in this habitat.

As reported herein, *S. robustus* from canyon mouth estuaries (e.g., the mouths of Eagle and Bell Canyons and Arroyo Burro, all on the South Coast of Santa Barbara County) may be a regional endemic entity that has different spikelets, achenes, and leaf-sheath orifices than *S. robustus*, a species that occurs on the margins of bays such as at Newport Backbay, San Francisco Bay, and many estuaries in eastern North America. A detailed taxonomic study of *Scirpus* in estuaries of California would be a worthwhile endeavor.

Vertebrate animal resources at Devereux Slough also reflect the physical conditions described herein. Schultz (1987) found that fish species richness (four species) in this estuary was low, "...because it lacks the marine fish visitations...common to other systems." However, the diversity was found to be within the ranges for comparable systems in California. One fish of interest, a mudsucker (*Gillichthys mirabilis*) was found to be "important in densities" at Devereux Slough, but is not often dominant in other estuaries (Schultz, 1987). The endangered tidewater goby, which is characteristic of many brackish canyon mouth estuaries, was not reported from Devereux Slough by Schultz. In contrast to fish richness, bird richness at Devereux Slough and vicinity is significant (i.e., 268 species; M. Holmgren, UCSB Vertebrate Museum, pers. comm., 1990) and apparently is as great or greater than any area of comparable size in California. The many habitats and seasonal variations in hydrology, plus proximity of this estuary to habitats such as marine wetlands, dunes, grassland and scrubland, and woody cultivated species, apparently accounts for this richness.

Bay Estuaries. Estuaries with large areas of subtidal habitat (bays) and low elevation salt marsh on the bay margins

are another very different category of estuary. Examples include Bolsa Chica (Fig. 4), Anaheim Bay (Fig. 5), Upper Newport Bay, and San Diego Bay. There is a strong marine influence in these estuaries because of the consistently open and generally broad mouth, the large body of marine water that floods habitats, and the low elevation of adjacent marshes that receive diurnal tidal flooding. Regarding the Tijuana Estuary in San Diego County, Zedler and Nordby (1986) demonstrated that it "...is a highly variable system that may best be termed an intermittent estuary. During the winter wet season, its waters are diluted by rainfall and streamflow; during the rest of the year, it is an extension of the ocean." Bay estuaries generally do not occur in areas of rapid geologic uplift and landscape evolution (e.g., the coastline of the Santa Ynez Mountains in Santa Barbara and Ventura counties). However, they can occur in flooded river mouths and valleys (e.g., Tijuana Estuary; Zedler and Nordby, 1986) and in coastal basins (e.g., Anaheim Bay) that have received extensive flooding or submergence during the last post-glacial rise in sea level. Zedler (1982) provided a general review of the characteristics of bays and other estuaries in southern California.

Subtidal habitat (Estuarine Deepwater Habitat) of bay estuaries often support beds of eel grass (*Zostera marina*). Intertidal mudflats adjacent to subtidal areas provide extensive habitat for Unconsolidated Shore Estuarine Wetland generally dominated by benthic invertebrate species. Other intertidal flats and banks provide habitat for Estuarine Emergent Wetlands, including low marsh dominated by cordgrass (*Spartina foliosa*), middle marsh generally dominated by pickleweed (*Salicornia virginica*), and hypersaline upper marsh often dominated by Parish's glasswort (*Arthrocnemum*

subterminale) and shoregrass (*Monanthochloe littoralis*). Many other vascular plant species, including those such as saltwort (*Batis maritima*), coastal saltgrass (*Distichlis spicata* ssp. *spicata*), California sea lavender (*Limonium californicum*), and estero seepweed (*Suaeda esteroa*), often characterize particular zones and can be associated with the above species or may even dominate the vegetation in some areas. This zonation associated with southern California bay estuaries is reflective of the large diurnal tidal amplitude. Brackish marsh vegetation generally dominated by *Scirpus* spp. and narrow-leaf cattail (*Typha domingensis*) occurs where streams or rivers empty into bays. The varied topography and size of intertidal habitats, and associated variations in flooding and salinity regimes, can result in a rich mosaic of plant associations. Where bays occur at the mouths of rivers, catastrophic flooding followed by a prolonged period of discharge can change the salinity regimes for periods sufficiently long enough to result in the downriver displacement of salt marsh vegetation by brackish marsh vegetation (Zedler and Nordby, 1986).

The fauna of bays and adjacent wetlands also is rich (Zedler, 1982). Various mollusks (e.g., 28 bivalve and 18 snail species at Tijuana Estuary) and crustaceans (e.g., 25 species including 19 crabs and shrimp at Tijuana Estuary) characterize the subtidal and/or intertidal habitats (Zedler and Nordby, 1986). Bays also provide habitat for the greatest numbers of fish species (e.g., 40 species at Tijuana Estuary; Zedler and Nordby, 1986), including many marine species that have access to these estuaries because of the consistently open mouths. They are important nurseries for the economically important California halibut (*Paralichthys californicus*) (Onuf and Quammen, 1990).

Spartina-dominated marshes provide excellent breeding habitat for the endangered light-footed clapper rail, and high marsh vegetation usually supports breeding populations of the endangered Belding's savannah sparrow. In summary, the large size and thorough tidal flushing contribute to the overall habitat and biotic richness of these estuaries.

Structural Basin Estuaries

In regions with considerable tectonic activity, down-faulted or down-folded structures along the coast support estuaries of moderate size (200-300 acres). In Santa Barbara County, the South Coast region occurs along the southern side of the Santa Ynez Mountains and includes uplifted coastal mesas and down-faulted basins such as the one containing Goleta Slough or down-folded (synclinal) basins such as the one containing Carpinteria Salt Marsh (Fig. 6). These structural basin estuaries have steep but short watersheds to about 1130 m (3500 feet) in elevation, and are characterized by occasional catastrophic flooding and sedimentation, particularly from large storms that may occur after chaparral fires in the adjacent foothills and mountains. Today, the estuaries at Goleta (Fig. 7) and Carpinteria may represent late stages of estuarine ecosystem succession, whereby prehistoric bays or lagoons that once may have occurred in these areas are now largely filled and lack extensive subtidal and low marsh habitats. Agricultural and urban development of the South Coast have resulted in fragmentation and infilling of much of the estuarine wetland. Without artificial structures, such as the revetments at Carpinteria Salt Marsh, sand spits (produced by long shore drift of sand) close the mouths, particularly during periods of drought, causing potentially

Fig. 1. Ventura River Estuary, Ventura County. Oblique aerial view northward illustrating parallel transportation corridors (Southern Pacific Railroad, foreground; U.S. Hwy 101; and Main Street, background). This river mouth estuary is characterized by perennial freshwater runoff, occasional breaching of the sand and cobble mouth barrier and subsequent tidal flushing, and lack of hypersaline habitats. As illustrated, the mouth is partially open and point bars are exposed in the estuary and colonized by brackish marsh species. Surface salinity may be reduced to close to 0 ppt when the mouth is closed and ponding occurs for extended periods. Photograph provided by M. H. Capelli.

Fig. 2. Devereux Slough at Coal Oil Point Natural Reserve, UCSB. View northward across estuary toward the Santa Ynez Mountains during period when mouth barrier is breached. In this canyon mouth estuary, irregularly exposed mud flats are dominated by the generally submerged ditchgrass (*Ruppia maritima*), or if sufficiently elevated, by the emergent pickleweed (*Salicornia virginica*) (e.g., center). Larger channels are generally permanently flooded. Ponded winter runoff floods all habitats. Surface brackish to nearly freshwater conditions of winter and spring are replaced by hypersaline conditions of summer and fall.

Fig. 3. Devereux Slough at Coal Oil Point Natural Reserve, UCSB. View westward across dune swale wetland towards the Santa Ynez Mountains. In contrast to low-water brackish or saline conditions when the estuary mouth is occasionally open in winter (Fig. 2), or when ponded conditions become hypersaline due to evaporation in summer or fall, winter or spring ponded-condition water is only slightly brackish and may reach surface elevations of 7 feet mean sea level, depending on the height of the mouth barrier. This ponded brackish water extends into the dune swale wetland, where California bulrush (*Scirpus californicus*) (center) dominates portions of the estuarine wetlands. These wetlands do not become hypersaline even when desiccation occurs.

Fig. 4. Bolsa Chica, Orange County. View southward across open water habitat of this bay estuary. During high tide as illustrated here, low marsh intertidal mud flats are flooded and are not separable from subtidal deepwater habitats. Because it is permanently open to the ocean, Bolsa Chica receives regular tidal flushing and supports extensive salt marsh vegetation.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 5. Seal Beach National Wildlife Refuge, Anaheim Bay, Los Angeles/Orange Counties. View eastward across wetlands of this bay estuary. Low marsh vegetation is dominated by *Spartina foliosa* (center). Mud flats exposed at low tide occur at elevations below low marsh. Subtidal deepwater habitat is adjacent to these intertidal habitats, but out of view.

Fig. 6. Carpinteria Salt Marsh, Santa Barbara County. Oblique aerial view westward across estuary (center) and along axis of structural basin (syncline). City of Carpinteria occurs to the east (bottom). Flood control channels for Franklin and Santa Monica creeks are visible in the eastern and southern portions of the estuary. The majority of the estuarine wetlands are dominated by pickleweed (*Salicornia virginica*). Photograph provided by C. C. O'Shock.

Fig. 7. Goleta Slough Ecological Reserve, Santa Barbara County. View northward, across axis of the down-faulted basin estuary, toward the Santa Ynez Mountains. Subtidal deepwater habitat is restricted to narrow channels or excavated flood control structures. Vegetated intertidal flats are dominated by pickleweed (*Salicornia virginica*).

Fig. 8. Deltaic Gradient at Carpinteria Salt Marsh. Aerial view over this basin estuary illustrated the gradient (arrow) of the coalesced delta of Franklin and Santa Monica Creeks. Gradient includes "low marsh" (dark color), salt flat evaporation zone (light color), and upper marsh transition (gray color). Photograph by Pacific Western Aerial Photographs.

Fig. 9. Upper marsh transition, Carpinteria Salt Marsh. View westward across delta, from irregularly flooded upper marsh transition (foreground) toward salt flats (center) and regularly flooded "low marsh" (background). *Lasthenia glabrata* var. *coulteri* (light colored flowers in foreground) is one of the upper marsh annuals that germinate following winter rainfall that reduces soil salinity during periods of lower high tides. Perennial plant cover of the upper marsh is dominated by *Arthrocnemum subterminale*.

serious degradation of this estuarine environment (Ferren, 1985), which is typically more marine rather than freshwater influenced.

In contrast to bays, the smaller structural basin type of estuary lacks extensive subtidal habitat and lacks low marshes dominated by cordgrass (*Spartina foliosa*). In the basin estuaries, "low marsh" is represented by the physical and vegetational characteristics of the "middle marsh" of bays, and usually is dominated by pickleweed (*Salicornia virginica*). The narrow, shallow subtidal habitats lack eel grass (*Zostera marina*); however, as in some bays, ditchgrass (*Ruppia maritima*) is occasionally found in shallow, poorly-flushed channels (e.g., Goleta Slough; Ferren and Rindlaub, 1983), but apparently does not dominate extensive mud flats as it does at Devereux Slough. Middle and upper marsh vegetation is similar to vegetation adjacent to bays, although hypersaline non-vegetated salt flats and upper marsh transitional vegetation along deltas (Ferren, 1985; Callaway et al., 1990) are apparently proportionately more common in structural basin estuaries.

Channel habitats are often artificially created or modified for flood control purposes in these estuaries. They support mollusks (e.g., six bivalve and one snail species at Carpinteria) and crustaceans (e.g., four crab species at Carpinteria) that are similar to those in bay estuaries, but are less rich in species. For their moderate size, these basin estuaries can have a rich fish fauna if the mouths remain open. For example, 18 species including juvenile California halibut are reported at Carpinteria Salt Marsh (Schultz, 1988, and pers. comm., 1990). Structural basin estuaries provide important upper marsh nesting habitat for Belding's savannah sparrow, which reaches its northwestern limit at Goleta Slough.

The light-footed clapper rail, however, has been extirpated at the northern limit of its range in the estuaries at Goleta and Carpinteria, where it was last reported in 1969 and 1988, respectively (Lehman, 1982; R. Zembal, USFWS, pers. comm., 1990). The smaller size of the estuaries, lack of buffer habitats, lack of low marsh dominated by *Spartina*, and the abundance of introduced predators such as feral cats (*Felis domestica*) and red fox (*Vulpes fulva*) may have contributed to the loss of this species in structural basin estuaries.

Intermediate Estuaries

Although classification of estuaries can provide a useful tool for designing research and management programs, in reality each estuary is unique as defined by its size, nature of its watershed, latitudinal position along the coast, disturbance history, and relationship to the open ocean. However, because of the inter-relatedness among the various categories of estuaries as described herein, many estuaries exhibit characteristics of more than one category. Mugu Lagoon Estuary in Ventura County, for example, is the northwestern-most estuary in southern California with some characteristics of bay estuaries. Historically, Mugu Lagoon Estuary had a small watershed (ca. twice the size of the wetland) and received little runoff from the surrounding Oxnard Plain or Santa Monica Mountains; freshwater marshes probably occurred contiguous to the lagoon, which is estimated to have had a tidal prism sufficient to keep the mouth of the lagoon open to the ocean (Onuf, 1987). This coastal ecosystem was described by Onuf (1987) to have been "...a true lagoon rather than an estuary for most of its existence", because of its general lack of freshwater influence. In 1884, Mugu Lagoon "became an estuary"

when Calleguas Creek was channelized and directed into the lagoon, thereby expanding the watershed (to 500 times the size of the lagoon) and increasing the influence of freshwater runoff, but also dramatically increasing sedimentation from development on steep slopes in the region (Onuf, 1987).

Mugu Lagoon Estuary presently has enough subtidal habitat to support estuarine aquatic beds dominated by eel grass (*Zostera marina*), and has narrow margins of low marsh that support a limited occurrence of cordgrass (*Spartina foliosa*) and the associated low to mid-marsh species such as saltwort (*Batis maritima*) and Parish's glasswort (*Salicornia bigelovii*), both of which reach the northwestern limits of their range in this estuary. Onuf (1987) has reported on the similarity of environment and biota between this estuary and large bay estuaries in southern California, particularly Anaheim Bay, Upper Newport Bay, and Tijuana Estuary. Mugu Lagoon Estuary, however, occurs in a region of extensive watershed alteration and adjacent features of geologic uplift; thus it receives extensive sediment loads as in structural basin estuaries, but lacks the force of large river floods to remove the loads even though the watershed of Revelon Slough and Calleguas Creek flow into it. Onuf (1987) has demonstrated the extensive loss or conversion of bay habitats during the past 20 years as a result of sedimentation. With continued sedimentation, all characteristics of a bay estuary may be lost at Mugu Lagoon Estuary.

PLANT DISTRIBUTION AND SOIL SALINITY IN THE UPPER MARSH.

Recent research conducted at the University of California, Santa Barbara, on the vegetation of a structural basin estuary has revealed characteristics that

may be restricted to estuaries in the Mediterranean type of climate. Streams that drain the steep watershed of Goleta Slough and Carpinteria Salt Marsh, for example, produce coalesced deltas that have filled in portions of these estuaries and produced a low marsh to upland habitat gradient (Figs. 8, 9). At Carpinteria Salt Marsh, the geologic setting in combination with climate and tidal flushing has produced distinct zonation of the vegetation in the upper marsh.

Field studies (Callaway et al., 1990) along transects at a delta in Carpinteria Salt Marsh included measurement of elevation, tidal flooding frequency, soil bulk density, slope angle, seasonal changes in soil salinity, and plant species zonation. By multivariate analysis of sample plot data, Callaway et al. (1990) identified four zones along the deltaic gradient. A low elevation zone, dominated by pickleweed (*Salicornia virginica*) and flooded frequently by tides throughout the year, had soil salinities that were high (marine to slightly hypersaline) throughout the dry and wet seasons. A non-vegetated salt flat was characterized by low slope angle and dense, consistently hypersaline soil. A transitional zone in the upper marsh, dominated by the perennial Parish's glasswort (*Arthrocnemum subterminale*) and "winter annuals" such as salt marsh goldfields (*Lasthenia glabrata* var. *coulteri*), salt marsh sand spurrey (*Spergularia marina*), and sickle grass (*Parapholis incurva*), was characterized by hypersalinity in the dry season and low soil salinity in the wet season. A grassland zone, largely above the limit of tidal flooding and dominated by introduced annual grasses, was characterized by low soil salinities in both the dry and wet seasons. A comparison (Fig. 10) of plant species, elevation, tidal flooding, and salinity along a transect

Fig. 10. A. Species Cover and Elevations for 153 Plots on three Integrated Transects at Carpinteria Salt Marsh. Plants are arranged on the ordinate by their horizontal distance from the lowest plot in the marsh; the ordinate is not to scale; (...) = elevation; MHHW = mean higher high water; Max. H.W. = maximum high water. B. Soil Salinity on the Integrated Transects at Carpinteria Salt Marsh; mosm/ml = milliosmols/milliliter. The ordinate is the same as 10A. When comparing 10A with 10B, note the relatively consistent saline soils of "low marsh", the consistent hypersaline soils of the salt flat, the euryhaline (fluctuating salinity) soils of the high marsh transition, and the consistently low salinity of the grassland. Salt marsh "winter" annuals of the upper marsh are confined to the euryhaline soils. (From Callaway et al., 1990).

illustrates the correlative relationships among these estuarine characteristics.

Experimental studies (Callaway et al., 1990) of several winter annual species from zones along the deltaic gradient at Carpinteria Salt Marsh found that their germination and growth response to different salinities corresponded to their zonation patterns in the field. The survival of scattered perennials in the

fluctuating (euryhaline) conditions of the upper marsh transition zone is partially dependent on the ability to tolerate summer and fall hypersalinity. Winter annuals, however, survive the dry season as seeds, eliminating the need to adapt physiologically to the dry season hypersalinity. Winter precipitation, in the absence of tidal flooding on the transition zone during this season, apparently

leaches salts from the soils to low levels tolerated by the annual species.

Annual plant species have been reported (see Callaway et al. 1990) from the upper zones of other Mediterranean-climate salt marshes (e.g., in Europe, Africa, Australia, and elsewhere in southern California). Quantification of the physical conditions under which winter annuals grow at Carpinteria Salt Marsh may have documented a phenomenon (i.e., euryhaline soils that support winter annuals among scattered perennial plants) that characterizes the transition zone of other Mediterranean-climate estuarine wetlands with similar habitat gradients.

FUNCTIONAL VALUES.

The functional roles of estuarine systems are many and often high in ecological and social value. Five major categories of wetland functional values (Sather and Smith 1984) include: (1) hydrology including flood control and shoreline protection; (2) water quality; (3) food chain support/nutrient cycling; (4) habitat; and (5) socio-economic. These categories may have varying degrees of importance depending, for example, on the type of estuary or latitudinal location of an estuary. In southern California, protection of mainland shorelines from damage by storm wave surges at high tide can be significant; however, the filling of the majority of estuarine wetlands, the urbanization of the margin of estuaries, and the development of watersheds (resulting in increased runoff and sedimentation in tidal channels) have apparently reduced the importance of this functional value of estuaries. Likewise, the values of water quality protection and enhancement also are diminished because ground water basins and perched water tables buffered from the marine environment by estuaries are now

themselves often degraded from agricultural or urban contaminants. Furthermore, because estuaries are environmental "sinks" at the lower end of watersheds, many of the contaminants (e.g., nutrients, heavy metals, petrochemicals, and pesticides) released into watersheds eventually drain and accumulate in estuarine ecosystems, which can become sites of concentrated pollutants.

Food chain support values are important for resident estuarine organisms (e.g., bivalves, gastropods, crabs), visiting organisms (e.g., various predatory birds and mammals), migratory organisms (e.g., anadromous fish and many birds), and non-estuarine species (e.g., marine organisms that benefit from nutrients and detritus flushed from estuaries). Quammen et al. (1990) proposed that "food chain support" for wetlands be defined as, "the production of organic matter and its direct or indirect use, in any form, by organisms inhabiting, or associated with, wetland ecosystems." The numerous primary producers, detritivores, herbivores, and predators associated with estuaries clearly demonstrate the importance of their food chain support values.

Associated with these food chain support values are habitat values for organisms restricted to or dependent upon estuaries during part of their life cycle. Such values are particularly critical for rare or endangered species (e.g., salt marsh bird's beak, light-footed clapper rail, and tidewater goby), whose very existence are dependent upon the survival of southern California estuaries and the environmental quality of the few that remain. Some species of fish spend at least part of their life in estuaries, which apparently serve as nurseries for younger individuals. Onuf and Quammen (1990) have concluded that, "...there is strong

presumptive evidence that the California halibut is dependent on protected shallow waters for most of the rearing of young-of-the-year fish, and that the most suitable shallow water areas are parts of the least disturbed coastal wetland ecosystems remaining in the Pacific Southwest." In southern California where there are many rare, endangered, or habitat dependent estuarine species, the habitat functional values of estuaries are apparently the most important role. Onuf and Quammen (1990), for example, assert that, "The paramount values of these systems are values of rarity, not of abundance as may be true in other regions."

All of these types of function values affect the socio-economic functional values of estuaries. The latter values include consumptive values such as fisheries (e.g., California halibut, steelhead trout, and shellfish), mariculture, and commerce (e.g., harbors), and nonconsumptive values such as recreation (e.g., boating, bird watching, painting), research, education, aesthetics (e.g., natural heritage values of landscape and open space), and cultural heritage (e.g., native American resource use). The quality of life in southern California for all of its inhabitants has been enriched for millenia because of the presence of estuaries and their many functional values.

IMPACTS OF HUMAN ACTIVITIES

In spite of the numerous and varied functional values of southern California estuaries, the majority of their associated wetlands have been destroyed during the agricultural and urban development of the coast (Zedler, 1982; California Department of Fish and Game, 1983; California Coastal Commission, 1989). Considered for the region as a whole, impacts are as varied as the resources they affect, but can be grouped

into physical and biotic types. Physical impacts such as infilling (e.g., a recent delta formed in Devereux Slough and the historic filling of Carpinteria Salt Marsh to accommodate expansion of the City of Carpinteria) and fragmentation (e.g., the construction of berms and dikes in Goleta Slough and transportation corridors through the Ventura River Estuary) generally disrupt the dynamics of the ecosystem including, for example, tidal flushing. Impacts to water resources include degradation of water quality from contaminants such as nutrients (e.g., high nitrogen levels in agricultural runoff and ground water leakage into Carpinteria Salt Marsh and Upper Newport Bay, sanitary district effluent into the Ventura River, and raw sewage into the Tijuana Estuary), petrochemicals (e.g., effluents, runoff, and marine oil spills), metals, and pesticides (e.g., DDE accumulated in sediments due to greenhouse effluent into Carpinteria Salt Marsh).

Other water resource issues affecting estuaries include: (1) the channelization of creeks and loss of natural riparian corridors that flow into estuaries; (2) elimination of estuarine/riverine transitions when dams, culverts, and other obstructions are built in the vicinity of the upstream limit of estuaries; (3) the "appropriation of unappropriated water" from streams and rivers that flow into estuaries, thereby diminishing the influence of fresh water in the system (e.g., Goleta Slough, Carpinteria Salt Marsh, and the Ventura River); (4) the increase in runoff amounts and rates as a result of urban development that increases the amount of impervious surfaces causing more water to flow into estuaries and at faster rates than would occur naturally, as at Devereux Slough and Upper Newport Bay; and (5) the closure of mouths of highly marine-influenced estuaries because of artificial barriers or sandbars that

prevent tidal flushing, or the artificial opening of highly freshwater-influenced estuaries that changes the natural water and salinity regimes of estuaries. All of these impacts can have profound direct effects (e.g., destruction of habitat or organisms) or indirect effects (e.g., reduction of dissolved oxygen, increase or decrease in salinity) that degrade estuarine ecosystems and reduce their functional values.

Impacts to biotic resources are not only the result of alterations of the physical environment, but are also the result of biotic factors. Invasive non-native plant species such as hottentot fig (*Carpobrotus edulis*) and croceum iceplant (*Malephora crocea*) at Carpinteria Salt Marsh and giant reed (*Arundo donax*) at the Ventura River Estuary can outcompete native species in particular habitats. Introduced animals (e.g., feral cats and red fox) can be serious predators on endangered species such as the light-footed clapper rail, which apparently has been eliminated by these and perhaps other predators from some estuaries such as Carpinteria Salt Marsh. The change in density of native species also can be dramatic, as exemplified by extensive growths of the alga *Enteromorpha intestinalis* associated with excessive nutrient input that not only alters the character of substrates and water surfaces, but can further degrade water quality by depleting dissolved oxygen during decay. Humans are perhaps the most important biotic factor, because they are capable not only of initiating most of the above types of impacts, but also can reduce biotic richness by direct removal of organisms.

Although each of the five functional values may not be negatively impacted in every estuary, other than some remote canyon mouths, virtually every estuary in southern California has suffered impacts and some have been eliminated altogether

(e.g. the historic estero in the City of Santa Barbara). State and federal mandates now call for wetland restoration and creation. Such efforts will be "successful" only if they take into account: (1) the context of existing and potential future environmental conditions (e.g., accelerated rise in sea level), including deleterious impacts (e.g., continued degradation of water quality); and (2) the constraints of previous habitat destruction and development of restorable lands (e.g., flood control levees, dams, and transportation corridors).

GLOBAL WARMING AND SEA LEVEL RISE

Researchers and managers of estuarine wetlands will be faced with many opportunities in the future. Increasing interest in wetland functional values and interpretive programs, and new state and federal mandates for protection, restoration, and creation of wetland habitats, may result in the gradual slowing or end to the long-term trend in loss and degradation of wetlands. In spite of this prospect, however, we are faced with a new and potentially catastrophic impact to coastal wetlands. A predicted increase in global warming, and the associated environmental changes, may cause the extensive loss or alteration of wetlands in southern California.

Global warming is a product of the "greenhouse effect", a natural process whereby atmospheric gases absorb some of the infrared (heat) energy radiated from earth (California Energy Commission, 1989). This process is largely responsible for producing the warmer atmospheric temperatures under which life has evolved. Industrialization and exploitation of the earth's natural resources, however, have caused a substantial increase in the concentration

of carbon dioxide and other "greenhouse gases" in the atmosphere (Hengeveld, 1987). This increase is predicted to have a profound effect on the temperature of the atmosphere. With the doubling of carbon dioxide content above pre-industrial levels, a global average annual increase of 4° C has been predicted (Rind, 1989) to occur. These estimated changes in global climate are expected during the next century (California Energy Commission, 1989; Titus, 1989), although atmospheric recordings already reveal temperature increases (Hengeveld, 1987).

Impacts from global warming have been estimated with great uncertainty and much variability, as have the atmospheric changes themselves. Recent treatments of the subject (e.g., Smith and Tirpak, 1988; Titus, 1988; California Energy Commission, 1989; EPA, 1989), however, concurred on major categories of environmental change that would occur in response to atmospheric warming. In addition to increased concentrations of greenhouse gases and coincident higher temperatures, predictions for the next century included a corresponding increase in acid rain and ozone (Durman, 1989), potential change in patterns, amounts, and type of precipitation (J. E. Smith, 1989), and a rise in sea level (Titus, 1988, 1989).

Impacts to estuarine wetlands as a result of global warming would come largely from an anticipated rise in sea level. There has been approximately a 30 cm (12 inch) rise in sea level along much of the coast of North America during the past century (Titus and Barth, 1984). Global warming could raise sea level as much as one meter (3 feet) in the next century because of thermal expansion of oceans and the melting of ice sheets (Titus and Barth, 1984). A five to seven meter (35-45 feet) rise could occur over the next few centuries if temperatures rose sufficiently high to produce a melting

of the West Antarctic ice sheet (Titus and Barth, 1984). Accentuating the possible effects of sea level rise will be the simultaneous subsidence of some areas.

Because of the biological and socioeconomic values associated with estuarine wetlands and the sensitivity of these habitats to many impacts, much has been written recently on the potential effects of sea level rise as related to these resources. Modeling conducted for the EPA revealed that 40-73% of the wetlands studied in the United States could be lost by the year 2100, but that the potential formation of new wetlands might reduce this loss to 22-56% (Armentano et al., 1988). Other estimates include a 30-70% loss with one meter (3 feet) rise and 33-80% loss with a two meter (6 feet) rise, 90% of which would be in the southeastern United States (Titus, 1988). In California, 35-100% of the EPA study wetlands were projected to be lost during the period. This loss could be reduced to 1-18% if developed or protected (leveed) areas were abandoned to allow landward migration of wetlands (Armentano et al., 1988; Titus, 1988).

Estuarine wetlands as a whole are distributionally limited in California and are estimated to occupy only 10-20% of the coastal area, whereas 71% of the Atlantic and Gulf coasts of the United States support estuarine wetlands (Armentano et al., 1988). This limited occurrence is largely the result of an emergent coastline and loss due to agricultural and urban development. Landward migration of wetlands as a result of sea level rise will be constrained by abrupt topography and artificial barriers constructed to protect agricultural lands and urban areas. Several examples described below illustrate potential conflicts.

Carpinteria Salt Marsh

Carpinteria Salt Marsh, a 230 acre estuary in Santa Barbara County, is an excellent example of a southern California structural basin estuary that has received statewide recognition for its wetland values (MacDonald, 1976; Ferren, 1985). Carpinteria Salt Marsh Reserve is a 49 ha (120 acre) portion of this estuary that is owned and managed by the University of California Natural Reserve System. This wetland system supports rare or endangered species and also is important for its food chain support, research, educational, and aesthetic values. However, it is surrounded by residences on sand spits with sea walls, and by transportation corridors, commercial sites, and developed portions of the City of Carpinteria. Flood control activities (e.g., channel dredging and desilting, levee maintenance) are conducted to limit flooding potentials within the Carpinteria Valley and sedimentation within the estuary.

A one meter (3 feet) rise in sea level by the year 2100 could produce the following effects: (1) convert all intertidal vegetated wetlands to subtidal deepwater habitats or intertidal mudflats; (2) reduce the biological diversity and number of habitat types; (3) cause extirpation of the endangered Belding's savannah sparrow and salt marsh bird's beak, as well as numerous regionally rare plants such as salt marsh goldfields (*Lasthenia glabrata* ssp. *coulterii*); (4) cause the extirpation of local populations of invertebrates (e.g., pulmonate snails and grapsid crabs) that are important to the marsh food chain; and (5) reduce the value of the marsh to wading birds. Because real estate, transportation, and commercial land values of the adjacent uplands are likely to be protected by seawalls, levees, and fill to increase elevations, the estuary

would probably be confined to its current extent. Because flood control practices are designed to reduce sediment flows and accumulation, the elevation of the marsh substrates probably would not increase at a sufficient rate to support marsh vegetation under this scenario. However, sediments are produced in abundance, and it might be relatively easy to modify sediment management practices by: (1) no longer intercepting sediment before it flows into the estuary; (2) preventing sediment from flowing through the estuary in flood control maintenance channels; or (3) no longer storing sediment in spoil piles adjacent to wetlands.

Ventura River Estuary

The Ventura River Delta area, discussed previously, is an example of a site where a rise in sea level could be accommodated by existing land use practices and where landward migration of wetlands could occur. A one meter (3 feet) rise in sea level could cause the landward migration of intertidal marine wetlands and dunes and the upriver migration of estuarine wetlands and subtidal habitat. Such an event, however, would cause the displacement of riverine and palustrine wetlands as the estuary spreads across the emergent portions of the delta and flood plain. Other expected phenomena include a rise in and increased salinity of the water table, which would produce an expansion of permanent flooding in wetlands at the smaller "second mouth estuary" of the Ventura River. Abrupt topographic relief would limit the extent to which palustrine forested and scrub/shrub wetlands could be accommodated landward. Socio-economic impacts would include potential loss of transportation corridors (e.g., Southern Pacific Railroad), recreational facilities at Emma Wood State Beach and

adjacent lands, and agricultural development. The existing levee on the east side of the estuary and topographic relief would confine the expanded estuarine habitats to the existing flood management corridor. Elsewhere in southern California, management efforts at Tijuana Estuary in San Diego County also would accommodate landward migration of wetlands because important transition habitats and broad buffers have been provided (J. Zedler, Pacific Estuarine Research Laboratory, SDSU, pers. comm., 1989).

Opportunities

Many of the authors and agencies cited herein and Josselyn (1989) have presented various actions and research and planning opportunities associated with the predicted global warming and potential sea level rise. These are compiled and expanded below.

Actions to be taken now could include the identification and acquisition of areas where new wetland habitats can be created or where landward migration of wetlands can occur concurrently with sea level rise. This effort should be made for all latitudes. Associated with this action should be the preservation of genetic diversity of wetland species through protection of examples of all types of coastal wetlands and the use of botanical gardens to grow local examples of wetland plants. The most important action would be the significant and widespread reduction of greenhouse gas emissions to slow global warming and reduce impacts that would result from a rise in sea level.

Recommendations for research priorities include the compilation of baseline information on hydrology, salinity, sedimentation, biology, and quality of wetlands throughout the coastal portions of the state and the

implementation of monitoring plans for representatives of each wetland type to record changes in physical and biological aspects of wetlands. Museums, systematic collections, and agencies should be mobilized to provide a comprehensive description of sensitive wetlands and wetland species throughout their ranges. Research should be conducted on ecotypic variation of various widespread and dominant species to determine if some populations are more suited to potentially more stressful conditions. These species or ecotypes might be useful in future restoration efforts. Experimentation with wetland restoration and creation projects, such as those conducted by the Pacific Estuarine Research Laboratory in San Diego County, should be conducted to determine if successful efforts are possible for various types of wetlands, because entire wetland ecosystems may have to be reconstructed to offset losses, particularly due to sea level rise.

Many opportunities also exist for developing and implementing plans to offset impacts from sea level rise. Coastal communities should evaluate the cost effectiveness of protecting real estate versus abandoning areas to permit the migration of wetlands and identify and plan for specific areas where abandonment is feasible. In a similar fashion, they should evaluate the benefits of protecting palustrine wetlands and agricultural lands with levees versus allowing expansion of subtidal habitats or estuarine wetlands. All hazardous waste sites that could be inundated due to a rise in sea level should be relocated and the areas restored. Coastal mitigation projects should include plans that will accommodate environmental changes due to global warming; therefore, all coastal wetland restoration and creation projects should be designed to be compatible with possible effects of sea level rise. Flood

control districts should re-evaluate desilting and dredging practices in the estuary to determine if sedimentation in coastal wetlands should be permitted to accommodate wetlands at higher elevations. These actions, research goals, and plans could be integrated into long-term planning for regions, rather than abrupt changes in policies, and should be modified to be consistent with new information as it becomes available. We must be prepared to solve the many conflicts that will result between resource protection and urban expansion, which will be exacerbated to a considerable degree if the predicted accelerated rise in sea level occurs.

CONCLUDING REMARKS

As we proceed with new research and management initiatives for the remaining southern California estuarine wetlands, we undoubtedly will gain insight on the potential for the restoration of degraded habitats and for the creation of new or expansion of existing habitats. The richness of habitats and biota associated with the various types of estuaries is an important part of the natural heritage of California. Stewardship responsibilities for these resources have never been greater nor more critical for the preservation of wetland values. The role these values play in the lives of future generations depends on our actions today. The urbanized coast of southern California must be managed to accommodate high quality estuarine wetlands and deepwater habitats in their many forms and various latitudes. Twelve years ago, Onuf et al. (1979) concluded that management of California's coastal wetlands, "...was a matter of preserving and restoring a very meager and severely threatened resource." This management goal is still a challenge

for all of us.

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RIPARIAN WOODLAND: AN ENDANGERED HABITAT IN SOUTHERN CALIFORNIA

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INTRODUCTION

There is no precise inventory of North American wetlands prior to European contact, but it has been estimated that wetland resources covered over 200 million acres (80 million ha) in the lower 48 states when European settlement began (Frayer, et. al., 1983). By the mid-1970s over half of the total had been eliminated, and only an estimated 99 million acres (40 million ha) remained. Destruction of wetlands over the previous two decades had proceeded at 400,000 to 500,000 acres (160-200 thousand ha) per year. By 1975 California had lost 91% of its wetland habitats (The Conservation Foundation, 1989). A dramatic example of riparian woodland loss occurred in the Sacramento Valley, where there were an estimated 800,000 acres (325,000 ha) of riparian habitat in 1850 (Roberts, Howe and Major, 1980). In 1952 this resource had shrunk to 20,000 acres (8000 ha) and by 1972 there were an estimated 12,000 acres (5000 ha) - or 1.5% of the original habitat - remaining. By 1980, the rate of national wetland "alteration" had slowed to an estimated average of 275,000 acres (111,000 ha) per year (Office of Technology Assessment, 1984), although in some areas, such as rapidly developing southern California, habitat loss continued at a high rate. Between the mid-1950s and mid-1970s an estimated 14,877,000 acres (6,023,000 ha) of freshwater wetlands were eliminated (Office of Technology Assessment and

U.S.F.W.S. National Wetlands Trends Study, 1982). During this era, draining of wetlands for agricultural purposes dominated freshwater wetland habitat destruction of 11,720,000 acres (4,750,000 ha), or 79% of total losses - but rationales for converting wetlands to other land uses ranged from urban development of 925,000 acres (375,000 ha), or 6%, to flooding them behind hydroelectric projects, stream channelization, and filling them for agricultural use, among many others (Table 1). Current estimates of riparian habitat reduction in southern California floodplain areas have been as high as 95% -97% (Faber, et. al., 1989), a regional loss exceeding that of the endemic coastal sage scrub plant community. There is no question that riparian habitat in southern California is endangere. Global warming and a rising sea level in the next 150 years will claim another heavy toll for wetlands, particularly along the coasts. A few of the anticipated global warming impacts that will change riparian habitat distribution and perhaps even community structure to some extent, as summarized by Tonnessen (1988) and others, include:

- Air temperatures will be higher year-round which will increase evaporation and transpiration.
- It will be drier in the fall, drought will occur in the summer and there will be

Table 1.
Methods of altering wetlands (from The Conservation Foundation, 1989).

Physical

1. **Filling:**
- adding any material to change the bottom level of a wetland or to replace the wetland with dry land;
2. **Draining:**
- removing the water from a wetland by ditching, tiling, pumping, etc.;
3. **Excavating:**
- dredging and removing soil and vegetation from a wetland;
4. **Diverting water away:**
- preventing the flow of water into a wetland by removing water upstream, lowering lake levels, or lowering groundwater tables;
5. **Clearing:**
- removing vegetation by burning, digging, application of herbicide, scraping, mowing or otherwise cutting;
6. **Flooding:**
- raising water levels, either behind dams or by pumping or otherwise channeling water into a wetland;
7. **Diverting or withholding sediment:**
- trapping sediment, through construction of dams, channelization or other types of projects; thereby inhibiting the regeneration of wetlands in natural areas of deposition, such as deltas;
8. **Shading:**
- placing pile-supported platforms or bridges over wetlands, causing vegetation to die;
9. **Conducting activities in adjacent areas:**
- disrupting the interactions between wetlands and adjacent land areas, or incidentally impacting wetlands through activities at adjoining sites;

Chemical

1. **Changing nutrient levels:**
- increasing or decreasing levels of nutrients within the local water and/or soil system, forcing changes in the wetland plant community;
2. **Introducing toxics:**
- adding toxic compounds to a wetland either intentionally (e.g. herbicide treatment to reduce vegetation) or unintentionally, adversely affecting wetland plants and animals;

Biological

1. **Grazing:**
- consumption and compaction of vegetation by either domestic or wild animals;
2. **Disrupting natural populations:**
- reducing populations of existing species, introducing exotic species or otherwise disturbing resident organisms.

Selected riparian habitat alterations in southern California (including most impacts reviewed in Faber, et.al., 1989).

1. **Channelization:**
- "... eliminates all riparian habitat and wildlife values" (Faber, et.al, 1989); breaks continuity and connectedness of riparian corridor, fragmenting riparian habitat within a watershed; eliminates the wildlife corridor function of stream courses - whether lined or unlined channelization is employed; reduces habitat diversity and distribution within watersheds;
2. **Increased sediment loading:**
- caused by logging, clearing habitat for development, construction-related sediment generation, agriculture, road-building, overgrazing, and altering the fire cycle in natural upland vegetation, among other practices which generate sediment and increase vulnerability to erosion;

Table 1 (Continued)

3. Domestic or agricultural wells, ditching and draining of wetland sites:
- lowers water table, reduces wetted areas available to riparian vegetation;
4. Man's recreational activities:
- off-road vehicle (both motorcycle and four-wheel drive vehicle) and mountain bicycle use of streamchannels, riparian habitat and adjacent uplands as trails denudes habitat, increases erosion, and so forth; use of riparian trees and shrubs for firewood; camping and picnicing impacts; trash accumulation; graffiti and carvings on trees; shooting (glass, damaged vegetation); trails, roads, and human and pet waste in riparian habitat -among many other recreational impacts;
5. Gravel mining:
- disrupts the streambed, increases downstream sediment loads, alters the water table, and requires roading through riparian habitat;
6. Proliferation of exotic species:
- non-native plant species, such as castor bean, tamarisk, Indian tree tobacco, ice plant species, Pampas grass, and many other exotics are abundant in riparian settings (for example, there are 73 exotic plant species in the San Joaquin Marsh; also see Faber, et.al., 1989); non-native snails (Helix aspersa) consume vegetation;
7. Grazing:
- eliminates riparian habitat, degrades aquatic ecosystem values, increases sedimentation and erosion, and so forth;
8. Altering natural flooding and flow regimes:
- flood control, water storage, diurnal water level fluctuation impacts below hydroelectric facilities, and so forth (see Faber, et. al., 1989, for a discussion of flood-triggered seed production and dispersal);
9. Mitigation banking:
- allows regional elimination of riparian habitat, simplifies regional habitat diversity, promotes "all your eggs in one basket" syndrome by allowing consolidated offsite mitigation (for example, see the U.S. Army Corps of Engineers, 1989, proposal to mitigation bank 27 riparian sites averaging 2 acres each at a single mitigation project on Aliso Creek); loss of diversity of riparian habitat by focusing on establishing target species (willow-woodland, for example); utilization of non-local genetic stock in plantings;
10. Failed attempts at mitigation:
- lack of successful establishment of replacement communities, low species richness, lack of mitigation for wetland habitat altered to allow a site for target species (mitigation) plantings (for example, elimination of sedge or Baccharis for replacement with willow- woodland); long time spans between habitat destruction and functional replacement (see Kusler, 1989; 1990);
11. Impacts of lowered water quality:
- though not clearly understood for all forms of pollution, "first flush" runoff from streets and freeways; herbicide, fungicide, pesticide and fertilizer laden runoff from golf courses, agricultural fields, nurseries, and to a lesser degree urban residential areas; industrial pollution; reclaimed sewage water (nutrient and salt rich) runoff from cities using it for city and large development landscape watering; chlorinated or chloraminated runoff; seepage from septic tanks or systems, all degrade water with varying potential impacts upon aquatic ecosystems and riparian communities (especially herbs and water quality-sensitive under story species). Synergistic and cumulative impacts as pollutants accumulate in sediments;
12. Urban development, creation of golf courses, flooding behind water storage or flood control projects, conversion to agricultural uses, freeway and other road building in riparian corridors all directly contribute to habitat loss and alteration (see the first portion of Table 1).

greater than average precipitation and runoff in the winter and spring.

- The Sierran snowline will be found at higher elevations and winter rain will be more frequent at intermediate elevations.

- There will be greater air pollution (ozone, acidic pollutants) transported to higher elevations.

- There will be a northward shift of storms, resulting in more monsoonal storms reaching into the southern Sierra during the summer.

- Major climatic zones could shift as much as 30-60 km northward and in mountainous areas the shift would be in elevation not latitude (see Ferren, 1989, and Byron, Jassby and Goldman, 1989, for numerous additional potential future influences on freshwater wetland systems and other references in this burgeoning area of research).

Increased need for water by agriculture and urban requirements will stress systems, and will make riparian habitat preservation planning extremely important. With lower water volumes pollution will be less diluted which will also cause an increased impact on riparian and aquatic habitat. As Ferren (1989) stated, "In urban areas, the likely increased need for water, increased levels of ozone, and the potential need to create new reservoirs in rivers and canyons all could contribute to the loss and degradation of riparian communities." In short, global warming is not good news for riparian habitats and will exacerbate the current situation.

CHARACTERISTICS OF RIPARIAN ZONES

There are many anthropocentric as well as biocentric "benefits" afforded by wetland habitats (Table 2). Not the least of these is that nearly 35% of our endangered species depend upon wetland habitats although they comprise less than 5% of our lands (The Conservation Foundation, 1989).

Riparian zones usually have two essential characteristics: laterally flowing water that rises and falls at least once during the growing season, and a strong connectedness with other ecosystems (Ewel, 1978). They are buffers and filters between man's development and water resources. Riparian habitat is ecotonal in nature with an elongate shape and very high edge to area ratio (Odum, 1978). Riparian areas can range in width from less than a meter to hundreds of meters or more in a floodplain. Riparian habitat has a large energy, nutrient and biotic interchange with the aquatic systems on the one hand and with the upland terrestrial ecosystem on the outer margin. It exhibits the "edge effect"; the density and diversity of species tends to be higher at the land/water ecotone than in the adjacent uplands. Many animal species are riparian habitat obligates and large mammals that require access to water use the band of riparian habitat as a wildlife corridor. Hydroperiod and a natural hydrologic cycle are keys in determining vegetative composition and productivity. Riparian habitat when viewed at any point in a drainage is somewhat of an ecosystemic snapshot, and it's important to understand a site's context in terms of what lies below and above. Although botanists often don't think much about it, riparian vegetation in various stream sections in a watershed plays a large role in the energy flow in stream ecosystems (Figure 1). While this approach is diagrammatic, it is useful as long as one keeps in mind that these generalities

**Table 2. Wetlands functions, including biocentric and anthropocentric elements
(from The Conservation Foundation, 1989, as adapted from Kusler, 1983)**

- A. *Flood conveyance* - Riverine wetlands and adjacent floodplain lands often form natural floodways that convey flood waters from upstream to downstream points.
- B. *Barriers to waves and erosion* - Coastal wetlands and those inland wetlands adjoining larger lakes and rivers reduce the impact of storm tides and waves before they reach upland areas.
- C. *Flood storage* - Inland wetlands may store water during floods and slowly release it to downstream areas, lowering flood peaks.
- D. *Sediment control* - Wetlands reduce flood flows and the velocity of flood waters, reducing erosion and causing flood waters to release sediment.
- E. *Fish and shellfish* - Wetlands are important spawning and nursery areas and provide sources of nutrients for commercial and recreational fin and shellfish industries, particularly in coastal areas.
- F. *Habitat for waterfowl and other wildlife* - Both coastal and inland wetlands provide essential breeding, nesting, feeding, and predator escape habitats for many forms of waterfowl, other birds (see Zenbal's chapter), mammals, and reptiles.
- G. *Habitat for rare and endangered species* - Almost 35 percent of all rare and endangered animal species are either located in wetland areas or are dependent on them, although wetlands constitute only about 5 percent of the nation's lands.
- H. *Recreation* - Wetlands serve as recreation sites for fishing, hunting, and observing wildlife.
- I. *Water supply* - Wetlands are increasingly important as a source of ground and surface water with the growth of urban centers and dwindling ground and surface water supplies.
- J. *Food production* - Because of their high natural productivity, both tidal and inland wetlands have unrealized food production potential for harvesting of marsh vegetation and aqua-culture.
- K. *Timber production* - Under proper management, forested wetlands are an important source of timber, despite the physical problems of timber removal.
- L. *Historic, archaeological values* - Some wetlands are of archaeological interest. Indian settlements were located in coastal and inland wetlands, which serve as sources of fish and shellfish.
- M. *Education and research* - Tidal, coastal, and inland wetlands provide educational opportunities for nature observation and scientific study.
- N. *Open space and aesthetic values* - Both tidal and inland wetlands are areas of great diversity and beauty and provide open space for recreational and visual employment.
- O. *Water quality* - Wetlands contribute to improving water quality by removing excess nutrients and many chemical contaminants. They are sometimes used in tertiary treatment of wastewater.

aren't hard and fast.

There are four primary factors governing stream ecosystems (modified from Cummins, 1979; Bowler, 1988):

- The annual hydrographic pattern (flooding cycles, low flow cycles, and seasonal variation), which determines scouring rate and the rate of hydrologic pruning, nutrient and sediment flow a riparian setting receives; hydroperiod determines the resilience of a riparian community.
- The geomorphic setting (the geology, gradient, and shape of the channel), which defines the slope and influences the non-sediment edaphic factors.
- The vegetative setting (riparian vegetation characteristics, particularly in the headwater reach), which can influence colonization rates, species diversity and the composition of communities which survive heavy seasonal floods and scouring.
- Stream order (the size of the stream).

In discussing riparian habitat it is useful to review briefly some of the characteristics of streams and drainages in headwater, mid-reach and lower river sections because it's important to realize that the often distinct settings in different reaches of a stream or river directly influence the kinds of riparian habitat found in each. Tables 3 and 4 show some of the characteristic plants from riparian woodlands in southern California and from Orange County, broken down into stream reaches. Faber, et. al. (1989) present examples of community dominants in riparian settings at various elevations at sites throughout southern California, though stream reaches are not identified.

The concept of the river as an

energetic and ecosystemic continuum, as developed by Vannote, Cummins and others (Vannote, et. al., 1980; Knight and Bottorf, 1984), stresses the role that headwater vegetation plays in providing the coarse particulate organic matter which supports the predominantly heterotrophic community in the headwater reaches (Figure 1). Faber, et. al. (1989) presented an excellent synopsis of this relationship in southern Californian settings, although there is little data to fill out the broad ecosystemic functions known in other regions. As Faber, et. al. (1989) summarized, "Detritus provided by riparian vegetation is a source of up to 90 percent of the nutrients consumed by instream aquatic communities (Hubbard, 1977; Cummins, 1975; Merritt, 1978; Hart, 1975)." Furthermore, upland fire-adapted plant communities such as chaparral and coastal sage scrub may contribute nutrients to adjacent aquatic ecosystems through post-fire runoff (Faber, et. al., 1989).

The concept of connectedness (Ewel, 1978) plays a significant role in resilience, ensuring inflow of species after disturbance, but also exposes a system to the battering of impacts from above. In stream headwaters there is usually a heavy riparian cover, often with a closed canopy over the stream which limits the light reaching the streambed. This cover produces a heavy litter load and serves as the source for large quantities of coarse particulate organic matter, enhanced by deciduous trees and shrubs if the headwater elevation is great. The coarse particulate organic matter derived from riparian habitat becomes the primary foodsource for the predominantly heterotrophic community in light-limited, heavily shaded headwater situations. Headwater shading can also have a profound influence on water temperature. As is evident in Table 4, many of the

TABLE 3. Selected species occurring in Southern California riparian habitat in headwater, mid-drainage and floodplain settings. The abbreviations are keyed as follows: Deciduous = D; Evergreen = E; Headwater reach = HW; Mid-drainage = M; Floodplain = FP. (Adapted from Roberts, et.al., 1977 by Fred Roberts.)

1. Trees

A. Common:

<u>Alnus rhombifolia</u>	M (-FP)	D
<u>Platanus racemosa</u>	M - FP	D
<u>Populus fremontii</u>	FP	D
<u>Quercus agrifolia</u>	HW - M	E
<u>Salix laevigata</u>	FP	D
<u>Salix lasiandra</u>	FP	D

B. Uncommon:

<u>Acer macrophyllum</u>	HW	D
<u>Juglans californica</u>	M	D
<u>Populus trichocarpa</u>	M - FP	D
<u>Umbellularia californica</u>	HW - M	E

2. Shrubs

A. Common

<u>Artemesia douglasiana</u>	M - FP	E
<u>Baccharis emoryi</u>	FP	E
<u>Baccharis glutinosa</u>	M - FP	E
<u>Baccharis pilularis</u> subsp. <u>consanguineus</u>		E
<u>Cornus occidentalis</u>	HW	D
<u>Phoradendron tomentosum</u> subsp. <u>macrophyllum</u>	M	
<u>Rosa californica</u>	M - FP	D
<u>Salix hindsiana</u>	FP	D
<u>Salix lasiolepis</u>	HW - FP	D
<u>Sambucus mexicana</u>		D

TABLE 4. Riparian communities in headwater, mid-drainage and floodplain settings in Orange County, California. The abbreviations are keyed as follows: E = Evergreen; D = Deciduous. These "communities" are not formally named, and are based on observation. (Compiled by Fred Roberts.)

1. Headwater Settings, 800-1700 meters

Montane Riparian Woodland

<u>Acer macrophyllum</u>	D
<u>Quercus chrysolepis</u>	E
<u>Quercus agrifolia</u>	E
<u>Umbellularia californica</u>	E

2. Midreach Settings, 180-800 meters

Riparian Woodland

<u>Quercus agrifolia</u>	E
<u>Alnus rhombifolia</u>	D
<u>Platanus racemosa</u>	D
<u>Salix lasiolepis</u>	D
<u>Populus trichocarpa</u>	D
<u>Fraxinus velutina</u>	D

3. Floodplain Settings, 0-180 meters

Sycamore Alluvial Woodland

<u>Platanus racemosa</u> (widely scattered)	D
<u>Quercus agrifolia</u>	E
<u>Sambucas mexicana</u>	D

4. Lowland Riparian Forest

<u>Populus trichocarpa</u>	D
<u>Populus fremontii</u>	D
<u>Salix lasiolepis</u>	D
<u>Salix laevigata</u>	D

Toxicodendron and Artemesia douglasiana are not uncommon, and less frequently Platanus racemosa and Quercus agrifolia.

5. Willow Woodland

<u>Salix lasiolepis</u>	D
<u>Salix laevigata</u>	D
<u>Salix goodingii</u>	D

Mugwort often common in this communitiy as well.

6. Mulefat Scrub

<u>Baccharis glutinosa</u>	E
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Often there is a little Salix lasiolepis and Salix goodingii, but there isn't a real overstory development.

7. Willow Scrub

<u>Salix hindsiana</u>	D
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Some other willows as well.

Figure 1. Schematic representation of a Sierran stream shown as an expanding continuum from headwaters (0.5-6m wide; order = 1) to a medium-sized river (50-75m wide; order = 4-6), to a large river (up to 700m wide; order = 12). Abbreviations: P/R = ratio of gross photosynthesis to community respiration; CPOM = coarse particulate organic matter; FPOM = fine particulate organic matter; DOM = dissolved organic matter. Headwaters and large rivers are heterotrophic ($P/R < 1$), medium-sized rivers are shown as autotrophic ($P/R > 1$). (From Bowler, 1988, as adapted from Cummins, 1975, 1979; Knight and Bottorff, 1984; Vannote, et al, 1980.)

dominant woody species characteristic of headwater sites in Orange County are not deciduous, an interesting situation somewhat in contrast with other California settings.

In the mid-river reaches, the aquatic ecosystem shifts from a heterotrophic to an autotrophic community due, among other reasons, to a widening of the river valley and lack of a light-limited aquatic setting. There is usually relatively little shading by riparian vegetation in the middle sections of river systems, and there are higher nutrient and fine particulate organic matter levels from the upstream vegetation sources, which shifts the invertebrate community from shredders to grazers (Figure 1). The gradient is usually much flatter than headwaters and a well configured flood plain is often developed. The stereotypic "riparian forest" is often present in this section of the streamcourse.

The lower reaches of rivers near the mouth reflect a flat gradient with a broad floodplain. Under natural conditions this portion of a drainage would see seasonal flooding and blanketing with layers of soil and nutrients.

HUMAN IMPACT ON RIPARIAN HABITAT

As anyone living in southern California is aware, humans have dramatically altered, if not mangled, nearly every watershed in our region (Figure 2). It has been said that the third largest perennial freshwater tributary entering the ocean in California and the largest in southern California is the Hyperion sewage treatment plant outfall. Water diversions reduce riparian potential and dams similarly alter natural drainage processes. In southern California, the Sweetwater River, Tijuana River and San

Diego River were all perennial streams before water storage projects altered their natural hydrologic cycle.

By and large, dams produce half-lakes with depauperate terrestrial species diversity compared with free-flowing river reaches. As can be seen, for example, in San Diego County at Loveland Dam on the Sweetwater River near El Cajon, riparian vegetation is scoured out of the area below the dam. Residents familiar with the Sweetwater River in the reach below Loveland Dam recall white alder, Alnus rhombifolia, as a riparian community dominant, however, this species is now absent due to the altered stream flows caused by the water storage project (William Bretz, pers. comm.). Above the dam there is virtually no "riparian" vegetation, but a bathtub ring series of water level marks etched into a sterile hillside with emergent vegetation at the water's edge.

Though not a southern California situation, a site on the upper Middle Snake River in Idaho which my students and I studied, exhibited this phenomenon well (Jensen and Verhovek, 1980). In this study area within the Columbia Plateau and dominated by great basin sage associations and deciduous riparian forest along the river, we identified 158 vascular plant species, though only 78 species actually occurred within our transects. The Lower Salmon Falls Dam impoundment study site had a total of only 55 species, 34.5% of which were introduced. Along this impoundment there had been very little shoreline revegetation since the present water level was established around 40 years ago (the original riparian valley bottom was inundated in 1910 with a lower dam which was subsequently raised). The great basin sagebrush community came nearly to the water's edge and there was a discontinuous, thin band of a few meters

Figure 2. Five major classes of environmental factors that affect aquatic biota. The arrows indicate the kinds of effects that can be expected from human activities, in this case the alteration of headwater streams, excluding small impoundments (from Karr, et al., 1986, as modified from Karr, et al., 1983).

of low riparian vegetation. At three sample sites along the tailwaters below the dam, however, there was a very different species diversity and community composition, with 80 to 90 species present, a non-native percentage of 27%, and with large groves of hackberry (Celtis reticulata), river birch (Betula occidentalis), and squawbush (Rhus trilobata) - dominants of a rare deciduous riparian forest formation. In this study area riparian vegetation ranged between 0.5 and 75 meters from the water, and was typified by inconsistent distribution of species, mosaics of suitable habitat and many species which were infrequent or rare along the reach.

These results aren't surprising, since virtually all terrestrial, as well as aquatic, conditions are different before and after closing a water project. It's intuitively easy to see how eliminating habitat conditions along a natural streambed and raising the waterline to a height along a canyon wall normally dominated by sagebrush, chaparral or some other slope-inhabiting upland plant community, would produce a sterile shoreline.

Flood control projects - designed to capture water during flooding events and are therefore kept drained - are different in attendant vegetation from run-of-the-river hydroelectric impoundments, which are designed to store and release much smaller quantities of water. As Zembal documents elsewhere in this volume, the Prado Dam basin, designed as a storage facility for flood control, is a unique situation which has unintentionally created an interesting riparian situation with a simple community comprised of a few dominant species (Zembal, 1984a; see also Zembal, 1984b for data on the Santa Margarita River, still a natural riparian setting).

Another fundamental hydrologic

character which has been transformed in southern California is that of the natural flooding cycle and the scouring effect experienced in mid-river and lower reach areas. While diversion of instream flow has reduced the quantity of water available for natural processes in a drainage, water storage has similarly altered the timing of waterflow in a stream - occasionally altering the seasonal streamflow regime to suit perennial percolation requirements and inadvertently providing a water supply more dependable during the dry season than would occur without dams and impoundments. In this context, a number of models have been designed to examine instream flow needs for aquatic ecosystems, but in reality not much is known about longterm impacts of altered instream flows upon riparian vegetation and terrestrial ecology.

A summary of data from California basins by the U.S.F.W.S. WELUT team indicated that:

- 10% of average annual streamflow is the absolute minimal to sustain short-term survival of most aquatic life forms.
- 40% of average annual streamflow is required as a base flow to sustain an adequate habitat for (aquatic) survival.
- 60% of average annual streamflow is required to provide excellent habitat protection for most aquatic life forms and the majority of recreational needs.

Even if this controversial and simplistic "rule of thumb" for aquatic habitat is accepted, there is little real idea of how reducing streamflow to these degrees would alter riparian habitat, but it would likely be profound.

While water storage and streamflow diversion cause changes, flood

control causes others. As is intuitively obvious, flooding impacts increase progressively down a drainage, and the successional aspect of riparian communities caused by streamside scouring, similarly, is often most conspicuous in the floodplain reaches below headwaters. Flood control projects capture runoff and hold back the scouring, sediment, and nutrient-transporting flows which normally would flush out stream channels and thin vegetation. In a sense, the lower areas of southern California drainages are more advanced and denser in riparian formation (as much as streamflow allows, so that these are like the riparian formations of smaller streams) than they would have been without flood interruption, when succession would have been a more rapid process. The historic canyons and floodplains are overfit for the reduced flows in them today. Channelization, another element of flood control, is habitat evisceration, leaving vegetation and stream ecology with segmented, sterile breaks in connectedness (see Faber, et. al., 1989, for an excellent treatment of this ubiquitous habitat gutting in southern California).

In this context, riparian vegetation can be characterized in areas of flooding as having many of the opportunistic features of plants entering disturbed areas - rapid colonization, high productivity, good dispersal, and so forth. Especially at lower elevations, if a reach is not flooded and scoured, species diversity drops and woody species, especially willows, become dominant. This is particularly true in urban or agricultural runoff situations, in which water is continuous during otherwise dry seasons for natural streams of comparable size. This "urban slobber" or "nuisance flow" has created a "new" category of riparian habitats, which are particularly important in southern

California. Since the drainage capture of the Owens and Colorado Rivers, availability of water has resulted in runoff through drains, ditches and streamcourses which otherwise wouldn't occur. The U. S. Fish and Wildlife Service is in the process of inventorying California wetlands. The results of their survey will provide the first quantitative insight into the distribution and acreage of runoff-induced riparian habitat. In Orange County, the San Diego Creek and Laguna Lakes drainages are case histories that illustrate this phenomenon.

The San Diego Creek drainage as it exists today is an artifact of man's urban and agricultural needs. The broad contour of the drainage reflects an ancient and abandoned Santa Ana River channel; however, prior to the 1880s it was not a drainage emptying in the sense it does today into Upper Newport Bay. The end of the 1880s saw a gradual change from a pastoral land use to one more agriculturally based, rapidly leading to the need to drain and ditch the "Cienga de las Ranas," an extensive marshy wetland that formerly covered the Tustin Plain. The transition from range to fields occurred in a 20-year period, and the water table under the Tustin Plain, which had been ditched and drained beginning in 1906, dropped 10.2 meter between 1904 and 1928. Ditches became the watershed channels for storm flow, and by 1932 these channels connected with Upper Newport Bay. In 1942 the 47-acre (19 ha) Sand Canyon Reservoir was constructed and is currently owned and operated by the Irvine Ranch Water District. In the late 1960s San Diego Creek was channelized. The areas of the drainage that illustrate the effects of agricultural runoff and channelization particularly well are the sections below Sand Canyon Reservoir to MacArthur Bridge.

Over the past forty, but especially

during the last twenty years, the "stream" segment below Sand Canyon Reservoir has developed a lush closed-canopy willow habitat, which now extends all the way through Mason Regional Park to Culver Drive. Sunset Magazine recently touted the bicycle trail through the corridor as being one of the best touches of nature available to cyclists. While this is an excellent example of low elevation, willow-dominated habitat, it is actually a fairly simple community. The dominant willows are Salix goodingii, S. laevigata and S. lasiolepis. This cohort of willows has grown into trees of 5 or more meters in height. A few cottonwoods and a sycamore or two have been planted, so that the prospect is good for developing a multi-story habitat along the creek in future decades. Nonetheless, it is a skeleton, species-poor community compared with analogous elevational settings in natural streamcourses, such as the Santa Margarita River (Zemba, 1984b), though the scale in instream flow is significantly different between these sites.

The flood control channel between Campus Drive Bridge and MacArthur Bridge includes a sediment capture basin and the channelized creekbed with drop structures at both bridges. The sediment basin is cleared roughly each 5 years, and in the interim an interesting mosaic of plant communities develops. The flood control channel downstream of the sediment basin is also cleared, but less frequently. This site supports 59 species of plants, of which 59% are introduced. A majority of these species are rapid colonizers and are weedy.

Contrast this with the species-poor and simpler community in the Sand Canyon Wash above the "Christ College" reach. This riparian community is watered largely by agricultural runoff and has a poor herb and understory species

representation - perhaps due to chemicals used on the fields. In these sites there is a climax willow situation, where the tall and dense stands of only a couple of Salix species become dominant. In a sense this is almost a senescent community, while the flood control channel supports a more diverse but early successional group of species.

The Laguna Canyon complex of vernal pools, lakes, perched drainage habitat and the riparian corridor provides a different insight to artificially enhanced watersheds. At this site a vernal pool has been severely degraded by cattle and the proliferation of Eucalyptus in the pool basin. Overflow of the lake receiving urban runoff from a portion of Leisure World (a local retirement community) enters a perched groundwater lens and supports a rich and diverse riparian community - primarily watered by subsurface sources. A channel on the opposite side of Laguna Canyon Road has a large willow corridor - not unlike that in Mason Park. In this mosaic of wetland communities there are approximately 75 species, 61% of which are native.

Data on Table 5 suggest how selected local habitats rank in terms of introductions and disturbance. Though Table 5 represents only a few sites, it's interesting to consider the degrees to which local communities have been invaded by non-native species. One could hypothesize from these data that local lightly to moderately disturbed coastal sage scrub and chaparral communities have somewhat fewer introductions (around 21-17%) than heavily grazed grasslands (around 40%), and that ruderal habitats could have the highest proportions of introduced species (58%). Riparian habitat seems variable, but supports a substantial suite of non-native species (between 28 and 38%). An advanced growth flood-control channel

Table 5. An analysis of some selected habitats (data are summarized from the University of California, Irvine, 1989 EIR record; Zembal, 1984a; Laguna Canyon EIR record; the Natural Reserve System database on the San Joaquin Marsh; and Jensen and Verhovek, 1980 for the Snake River sites).

<u>Site</u>	<u>Habitat Type</u>	<u>No. of Sp.</u>	<u>% Native</u>	<u>% Exotic</u>
UCI	C. Sage Scrub	120	68%	32%
Lag. Canyon	C. Sage Scrub	110	79%	21%
Quail Hill	Grassland	67	57%	43%
Lag. Canyon	Grassland	133	62%	38%
Lag. Canyon	Chaparral	93	79%	21%
UCI SD CR.	Riparian	59	41%	59%
UCI	Riparian pockets	26	62%	28%
Lag. Canyon	Riparian/mixed Wetlands	75	61%	39%
Lag. Canyon	So. Oak Wdl.	122	70%	30%
Lag. Canyon	"Ruderal Habitats"	91	42%	58%
San Joaquin Freshwater Marsh		159	54%	46%
Prado Dam Basin & Environs.		311	68%	32%
Riparian/Dam Basin Only		143	63%	37%
Snake River				
Impoundment	Riparian	55	65%	35%
Freeflowing	Riparian	155	73%	27%

had a percentage of around 59% non-natives, on a par with "ruderal habitats." If true, this could be because bulldozed "ruderal" area habitat is similar to the periodically pruned flood control channel in providing "habitat" most suitable to rapidly invading introduced weedy species.

Finally, any discussion of riparian habitat would not be complete without at least mentioning the impact of cattle upon western stream habitats. Grazing has been one of the most profound degraders of riparian habitat on public lands in the

west, and the wreckage associated with cattle, such as trampling and subsequent increased runoff, destroys not only streamside vegetation but the instream ecology as well.

In conclusion, there is no question that riparian habitat is endangered in southern California. Wherever "natural" stands occur along historic watercourses they should be protected, and we should not be too proud as botanists to also demand "no net loss" standards for the fragments of habitat developing along

urban and agricultural runoff areas (See Kusler, 1989; 1990, for a thorough review of the successes and failures of the "no net loss" strategy of wetland preservation or replacement.

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RIPARIAN HABITAT AND BREEDING BIRDS ALONG THE SANTA MARGARITA AND SANTA ANA RIVERS OF SOUTHERN CALIFORNIA

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INTRODUCTION

The major synthesis of information on the plant communities of California (Barbour and Major, eds. 1977) excluded riparian habitats due to a lack of information. Known for very high productivity of fish and wildlife resources, riparian communities began to receive significant attention when it became evident that intensive disturbance was resulting in widespread loss and degradation (for example, see the many papers in Warner and Hendrix, eds. 1984). As the habitat base dwindled, several species of riparian birds that were once common, became rare (see Garrett and Dunn 1981, Faber et al. 1989). Finally in 1986, one of these, the least Bell's vireo (Vireo bellii pusillus), was added to the federal list of endangered species.

The U. S. Fish and Wildlife Service works with other Federal agencies in attempting to design water development projects that are minimally damaging and maximally responsive to the mandates and spirit of the Clean Water Act, National Environmental Policy Act, Fish and Wildlife Coordination Act, Endangered Species Act, and others. The need was clear by the early 1980s for the development of descriptive and quantified data on riparian parameters in various drainages of southern California to ensure adequate avoidance of, or compensation for, wildlife resources of high value. The Fish and

Wildlife Service began to use vegetational composition and bird use of project areas as generally indicative of habitat quality. Much of the original field work was concentrated along the Santa Margarita River in northern San Diego County and the Santa Ana River, particularly in the Prado Basin at the junction of Orange, Riverside, and San Bernardino Counties. Herein is a summary of some of the data on habitat composition and breeding birds of these riparian communities (see Zembal 1984, 1989, and Zembal et al. 1985 for additional data and analysis).

STUDY AREAS AND METHODS

The Santa Margarita River watershed comprises an area of approximately 740 square miles (1,917 square kilometers). The river is about 60 miles (96.6 km) long and empties into the Pacific Ocean just north of the city of Oceanside, 75 miles (121 km) southeast of Los Angeles. The lower 15 (24.1 km) or 16 miles (25.7 km) of the river are located on the U. S. Marine Corps Base, Camp Pendleton. Two major impoundments, Vail Lake and Lake Skinner, are located along the upper tributaries and control a total of half the drainage basin. Stretches of the lower river are completely wild and comprise one of the few relatively undisturbed riparian corridors remaining today in southern California. Reflecting the annual rainfall pattern characteristic

of southern California's Mediterranean climate, runoff and instream flow are greatest in the winter and early spring. Mean monthly flows vary among stations from as high as 477 cfs in February to nearly zero in August and September. A recently proposed project may result in a year-round base flow of about 75 cfs in the river.

The Santa Ana River is the largest river system in coastal southern California with a watershed of about 2,450 square miles (6,346 square km). Prado Dam, constructed by 1941 to control flooding, is located along the river at its confluence with Chino, Mill, and Temescal Creeks about 31 miles (49.9 km) from the Pacific Ocean. The Prado Basin is situated just west of the city of Corona and comprises 11,000 acres (4,452 ha), at least 4,400 acres (1,781 ha) of which support riparian vegetation. The dam is operated for flood control and water conservation, resulting in episodically prolonged inundation of the vast willow woodlands that persist behind the dam. The habitat in the basin is heavily man-influenced, resulting in species diversity and habitat complexity that differs markedly from those examined along the Santa Margarita River and other remnant sites on the Santa Ana River (for example, see Zembal 1989). Mean minimum discharge on the upper river is about 7 cfs with an average of approximately 83 cfs. The maximum discharge in the river was observed near the City of Riverside and estimated at 320,000 cfs. Field studies were conducted along a 24 mile (38.6 km) reach of the Santa Margarita River from the Pacific Ocean to Temecula Gorge, 6 April 1982 - 16 June 1983. The investigations were part of a feasibility study, funded by the Bureau of Reclamation, for the construction of two

dams on the river. Acreages were derived from planimetry of 1982 aerial photos of 1:6,000 scale. Data were collected on 8 study plots in the riparian habitats. The plots varied in size from 9.75 ha (24.1 acres) to 13.16 ha (32.5 acres) and totalled 92.03 ha (227.4 acres). Vegetational composition was measured along a total of 6,180 m (3.8 miles) of transect. Plant cover below 1.8 m (6 ft) was measured by line intercept; stem counts of trees and their size classes were taken along a 2 m (6.56 ft) wide belt centered on the transect tape; and canopy cover was assessed with two sightings through an ocular tube with crosshairs at one meter intervals. Breeding birds and visitors were documented on each plot with 8 visits for spot mapping (Van Velzen 1972) spaced throughout the breeding seasons in 1982 and 1983. Visits lasted from 4 to 6.5 hrs each. Additional details of the techniques used and study site locations are available in Zembal (1984).

Field investigations along the Santa Ana River and tributaries were concentrated in the Prado Basin and environs from 28 April 1983 through 20 April 1984, and from 31 March 1987 to 30 July 1987. Vegetational analysis included 26 - 0.1 acre (0.04 ha) circular plots for tree counts and 5 - 10, 1 square m (10.8 square ft) quadrats within each plot for ground cover estimates. Breeding birds and visitors were spot mapped during 8 visits to 8 different 10 acre (4 ha) plots in 1987. Additional details of these techniques and the study site locations are available elsewhere (Zembal et al. 1985, Zembal 1989).

THE RIPARIAN HABITAT

A total of 520 species (144 of these species, or 27.6% of the total are introduced), of 85 families of vascular

plants were identified from the environs of the lower Santa Margarita River. Approximately 148 of these species, or 28.5% of the total, were most commonly associated with floodplain and riparian habitats. The vegetational canopy of the river floodplain is heavily willow dominated. Tributaries, side canyons, and terraces of old sediment deposits on the edge of the floodplain were more likely to include canopy dominance by species other than willows.

Twenty-one species of plants contributed canopy along the belt transects. Willows were the most commonly encountered canopy forming species and arroyo willow (*Salix lasiolepis*) was the single most abundant and widespread of the 5 species observed. The other willows were black willow (*Salix gooddingii*), sandbar willow (*Salix hindsiana*), red willow (*Salix laevigata*), and yellow willow (*Salix lasiandra*). Other locally dominant canopy contributors included coast live oak (*Quercus agrifolia*), western sycamore (*Platanus racemosa*), wild grape (*Vitis girdiana*), giant reed (*Arundo donax*), Fremont's cottonwood (*Populus fremontii*), black cottonwood (*Populus trichocarpa*), and poison oak (*Toxicodendron diversilobum*) (Table 1).

The growth form of the outermost willows, those growing along edges, was often shrubby to subarborescent. This was particularly evident of the trees growing nearest the low flow channel or the upland interface, fringing established woodland stands. Inside stands of younger trees, the growth form was tall and straight, with the maximum stem densities encountered anywhere within willow woodland. Diameters at breast height of these trees did not exceed 3 inches (7.6 cm) and most were less than 1.5 inches (3.8 cm) (Table 2). Older stands comprised taller woodlands,

generally exceeding 5 m (16.4 ft) tall with stem diameters most commonly of 1.5 - 3 inches. These stands appear to thin over time to a gallery woodland stage in which the trees are more widely spaced, mostly of 3 - 6 inch (15.2 cm) diameter and greater, the foliage layer is still almost exclusively in the canopy, and canopy closure is nearly complete, so that understory is heavily shaded, mostly herbaceous, and local. With additional thinning of trees, specimen willows emerge with large spreading branches, foliage from the ground to in excess of 10 (32.8 ft) or 15 m (49.2 ft), and trunk diameters up to 15 inches (38.1 cm) or greater. At this stage, tree stem densities are minimal and shrubby riparian growth, often dominated by mulefat (*Baccharis glutinosa*), is interspersed. Scattered trees with full ground to canopy foliage development, interspersed with dense herbaceous to sub-shrubby growth was also typical of vegetated areas most recently effected by scour.

Over 100 species of vascular plants contributed to low ground cover in the riparian habitat along the Santa Margarita River (see Zembal 1984, for species lists and cover data). Although species composition in the understory varied greatly with location, several of the more important species were widely distributed and included mulefat, mugwort (*Artemisia douglasiana*), willow sprouts, Douglas' mulefat (*Baccharis douglasii*), poison oak, wild grape, wild blackberry (*Rubus ursinus*), the sweet clovers (*Melilotus* spp.), scouring rushes (*Equisetum* spp.), stinging nettle (*Urtica holosericea*), and nut-grasses (*Cyperus* spp.), among many others.

About 20% of the floodplain along the lower 12 miles of the Santa Margarita River and 13% along the upper river and side creeks was

Table 1. Tree stem density and canopy cover (%) on the study plots in riparian habitats along the Santa Margarita River. Adapted from Zembal 1984. See Appendix 1 for general plot description titles, as published.

Plot	Species	Tall Willow		Short Willow		Riparian with		Sycamore		Oak-Willow		Mixed	
		# ¹	% ²	#	%	#	%	#	%	#	%	#	%
Dike	<u>Salix lasiolepis</u>	34	38.3	45	42.3	27	4.8						
	<u>Salix gooddingii</u>	17	21.8	25	22.4	1	3.4						
	<u>Salix hindisiana</u>	3	1.5	1	-	-	-						
	<u>Arundo donax</u>	-	9.8	NC	4.2	-	-						
	Totals	54	71.4	71	68.9	28	8.2						
Shooting Range	<u>Salix lasiolepis</u>	29	27.8	18	18.0	25	12.0						
	<u>Salix gooddingii</u>	16	13.4	87	18.0	0.7	0.3						
	<u>Salix hindisiana</u>	28	3.7	18	4.4	6.0	0.9						
	<u>Arundo donax</u>	-	17.6	-	20.0	-	2.6						
	Totals	33	-	9	2.0	-	-						
		106	62.5	132	62.4	31.7	15.8						
Deluz Confluence	<u>Salix lasiolepis</u>	25	65.9	65	20.3			-	-				
	<u>Salix laevigata</u>	1	3.2	9	13.0			-	-				
	<u>Salix lasiandra</u>	0.2	0.7	-	-			-	-				
	<u>Salix hindisiana</u>	-	-	184	21.7			-	-				
	<u>Salix gooddingii</u>	-	-	9	11.6			-	-				
	<u>Platanus racemosa</u>	0.1	2.0	-	-			2	75				
	<u>Quercus agrifolia</u>	-	0.1	-	-			-	-				
	<u>Vitis girdiana</u>	-	1.6	-	-			-	-				
	<u>Rubus ursinus</u>	-	0.1	-	-			-	-				
	<u>Ricinus communis</u>	0.3	0.1	-	-			-	-				
	Totals	26.6	73.7	267	66.6			2	75				
Deluz Crossing	<u>Salix lasiolepis</u>	21	14.0	97	33.3					34	7.2		
	<u>Salix lasiandra</u>	17	23.1	26	23.7					14	9.8		
	<u>Salix hindisiana</u>	8	-	0.7	-					-	-		
	<u>Salix gooddingii</u>	-	-	-	-					-	-		
	<u>Platanus racemosa</u>	-	-	-	2.7					0.9	1.3		
	<u>Quercus agrifolia</u>	-	-	-	-					3	5.5		
	Totals	46	5.0	-	1.8					0.2	3.4		
			42.1	123.7	61.5					-	1.7		
										52.1	28.9		

Table 1 (Cont). Tree stem density and canopy cover (%) on the study plots in riparian habitats along the Santa Margarita River. Adapted from Zembal 1984. See Appendix 1 for general plot description titles, as published.

Plot	Species	Tall Willow Woodland		Short Willow Woodland		Riparian with Scattered Willows		Sycamore Woodland		Oak Woodland		Oak-Willow Woodland		Mixed Woodland	
		# ¹	% ²	#	%	#	%	#	%	#	%	#	%	#	%
Sandia Confluence	<u>Salix lasiandra</u>	8	39.0			3	-							6	9.8
	<u>Salix lasiolepis</u>	19	14.0			12	6.1							21	30.9
	<u>Salix hindsiana</u>	-	-			7	2.6							-	-
	<u>Nicotiana glauca</u>	-	-			1	-							-	-
	<u>Platanus racemosa</u>	-	-			-	-							0.1	1.9
	<u>Populus trichocarpa</u>	-	-			-	-							5	10.0
	<u>Quercus agrifolia</u>	-	2.9			-	-							-	-
	<u>Arundo donax</u>	-	-			-	0.9							-	-
	<u>Vitis girdiana</u>	-	11.0			-	-							-	14.1
	Totals	27	66.9			23	9.6							32.1	66.7
Sandia Creek	<u>Salix lasiandra</u>			10	30.0									1	4.7
	<u>Salix lasiolepis</u>			41	14.0									5	3.8
	<u>Salix laevigata</u>			-	-									-	1.2
	<u>Nicotiana glauca</u>			7	-									1	-
	<u>Platanus racemosa</u>			-	-									3	21.4
	<u>Populus fremontii</u>			-	-									0.1	1.6
	<u>Populus trichocarpa</u>			-	-									2	6.7
	<u>Quercus agrifolia</u>			-	-									2	16.1
	<u>Olea europaea</u>			-	-									-	-
	<u>Heteromeles arbutifolia</u>			-	-									-	0.2
Rainbow Creek	<u>Vitis girdiana</u>			-	6.0									-	3.5
	<u>Toxicodendron diversilobum</u>			-	-									-	0.4
	Totals			58	50.0									10	65.3
														16.1	65.2
	<u>Salix lasiolepis</u>	87	41.3	184	20.3									25	16.6
	<u>Salix lasiandra</u>	20	18.7	6	3.1									3	15.2
	<u>Salix hybrid</u>	4	-	-	-									-	-
	<u>Platanus racemosa</u>	0.1	0.8	-	-									1	21.1
	<u>Populus fremontii</u>	-	-	-	-									-	4.9
Rainbow Creek	<u>Quercus agrifolia</u>	-	-	-	-									1	12.1
	<u>Sambucus mexicana</u>	-	-	-	-									-	1.3
	<u>Vitis girdiana</u>	-	4.8	-	-									-	-
	Totals	111.1	65.6	190	23.4									30	73.9

Table 1 (Cont). Tree stem density and canopy cover (%) on the study plots in riparian habitat along the Santa Margarita River. Adapted from Zembal 1984. See Appendix 1 for general plot description titles, as published.

Plot	Species	Oak Woodland		Mixed Woodland	
		# ¹	% ²	#	%
De Luz Creek	<u>Salix lasiolepis</u>	-	-	2	4.2
	<u>Salix lasiandra</u>	-	-	0.5	0.5
	<u>Salix hindsiiana</u>	-	-	0.2	-
	<u>Platanus racemosa</u>	-	-	2	15.6
	<u>Quercus agrifolia</u>	-	-	0.4	9.7
	<u>Sambucus mexicana</u>	8	69.6	3.0	9.2
	<u>Toxicodendron diversilobum</u>	-	-	-	3.7
	<u>Rhamnus californica</u>	-	-	-	0.5
	<u>Baccharis glutinosa</u>	-	-	-	0.5
	Totals	8	69.6	8.1	43.9

¹ Stems per 100 m ² (1,076.4 ft)

² Percent canopy cover

Table 2. Diameter at breast height (DBH) of tree stems encountered on the study plots in riparian habitat along the Santa Margarita River. Adapted from Zembal 1984.

Plot

Species	Shooting Range										Deluz Confluence										Deluz Crossing														
	Dike										DBH Size Classes in Inches										Deluz Crossing														
	0-1.5	1.5-3	3-6	6-9	9-15	15-21	0-1.5	1.5-3	3-6	6-9	0-1.5	1.5-3	3-6	6-9	9-15	0-1.5	1.5-3	3-6	6-9	9-15	0-1.5	1.5-3	3-6	6-9	9-15	0-1.5	1.5-3	3-6	6-9	9-15	0-1.5	1.5-3	3-6	6-9	
<u>Salix lasiolepis</u>	255	127	91	2	1	-	274	50	21	1	173	53	81	33	10	601	36	4	1	-	601	36	4	1	-	601	36	4	1	-	601	36	4	1	
<u>Salix gooddingii</u>	127	66	29	1	-	1	409	44	9	-	9	-	-	-	-	1	-	3	-	-	1	-	3	-	-	1	-	3	-	-	1	-	3	-	
<u>Salix hindiana</u>	14	1	-	-	-	-	211	1	-	-	186	2	-	-	-	20	-	-	-	-	20	-	-	-	-	20	-	-	-	-	-	-	-	-	
<u>Salix lasiandra</u>	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	172	38	14	6	-	172	38	14	6	-	172	38	14	6	-	-	-	-	-	
<u>Salix laevigata</u>	-	-	-	-	-	-	-	-	-	-	14	1	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Tamarix</u> sp.	-	-	-	-	-	-	129	17	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Nicotiana glauca</u>	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Platanus racemosa</u>	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	3	5	3	1	-	3	5	3	1	-	3	5	3	1	-	-	-	-	-	
<u>Quercus agrifolia</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Ricinus communis</u>	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	397	194	120	3	1	1	1024	112	37	1	385	58	87	37	10	798	79	24	8	-	798	79	24	8	-	798	79	24	8	-	-	-	-	-	
Snags	3	2	-	-	-	-	6	-	-	-	11	4	1	-	-	7	1	2	-	-	7	1	2	-	-	7	1	2	-	-	-	-	-	-	
Total transect ₂ length	840 m	-	-	-	-	-	771 m	-	-	-	741.8 m	-	-	-	-	778 m	-	-	-	-	778 m	-	-	-	-	778 m	-	-	-	-	-	-	-	-	-
Trees per 100m ² (acre)	43 (1,725)	-	-	-	-	-	76 (3,082)	-	-	-	39 (1,591)	-	-	-	-	58 (2,365)	-	-	-	-	58 (2,365)	-	-	-	-	58 (2,365)	-	-	-	-	-	-	-	-	-

Species	Sandia Confluence										Rainbow Creek										Deluz Creek																
	Sandia Creek										DBH Size Classes in Inches										Deluz Creek																
	0-1.5	1.5-3	3-6	6-9	9-15	0-1.5	1.5-3	3-6	6-9	9-15	21-27	0-1.5	1.5-3	3-6	6-9	9-15	33-39	0-1.5	1.5-3	3-6	6-9	9-15	33-39	0-1.5	1.5-3	3-6	6-9	9-15	15-21	33-39	0-1.5	1.5-3	3-6	6-9	9-15	15-21	33-39
<u>Salix lasiolepis</u>	247	25	13	9	3	-	43	8	1	-	-	761	123	20	3	3	-	55	7	2	-	-	-	-	55	7	2	-	-	-	-	-	-	-	-	-	-
<u>Salix lasiandra</u>	59	21	7	4	2	-	4	1	1	2	-	109	30	14	4	-	-	5	3	2	-	-	-	-	5	3	2	-	-	-	-	-	-	-	-	-	-
<u>Salix laevigata</u>	-	-	-	-	-	-	9	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Salix hindiana</u>	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	
<u>Salix</u> sp.	-	-	-	-	-	-	-	-	-	-	-	18	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Populus fremontii</u>	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Populus trichocarpa</u>	27	2	4	6	1	-	11	-	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Platanus racemosa</u>	-	-	1	-	-	-	12	4	2	6	2	-	-	1	2	-	2	1	2	-	-	-	2	-	1	2	-	-	5	5	1	2	-	-	-	-	
<u>Quercus agrifolia</u>	-	-	-	-	-	-	11	3	3	1	4	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	1	5	-	-	-	-	-	
<u>Nicotiana glauca</u>	3	-	-	-	-	-	3	3	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Heteromeles</u>	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>arbutifolia</u>	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	6	13	3	-	-	-	-	6	13	3	-	-	-	-	-	-	-	-	-	
<u>Sambucus mexicana</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	
<u>Rhamnus ilicifolia</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	352	48	25	19	6	-	59	17	12	8	3	895	167	35	9	3	2	71	25	10	6	6	2	71	25	10	6	6	6	6	6	6	6	6	6	2	
Snags	23	3	6	-	-	-	-	-	-	1	1	7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total transect ₂ length	756.9 m	-	-	-	-	-	744.7 m	-	-	-	-	757.7 m	-	-	-	-	-	790 m	-	-	-	-	-	-	790 m	-	-	-	-	-	-	-	-	-	-	-	-
Trees per 100m ² (acre)	30 (1,204)	-	-	-	-	-	14 (576)	-	-	-	-	73 (2,974)	-	-	-	-	-	8 (323)	-	-	-	-	-	-	8 (323)	-	-	-	-	-	-	-	-	-	-	-	-

comprised of water channel and the adjacent, mostly sparsely vegetated, sandbars and scour channels. The remainder generally was heavily vegetated with low ground cover of overlapping plants and litter often providing 100% cover.

Plant collections from the Prado Basin and environs along the Santa Ana River, May 1983 - March 1984, resulted in the identification of 311 species (99 of which are introduced), from 65 families of vascular plants. Approximately 99 of these species, or 31.8% of the flora, were most typically associated with floodplain habitats. Another 12 species, or 3.9% of the total, were found in upland and wetland situations.

The vegetation of the Prado Basin wetlands differed markedly from that found along the Santa Margarita River. The willow forest was largely of the gallery stage and was species poor with a heavy dominance of black willows. Black willows are more tolerant of flooding than the other common riparian canopy species in southern California and have been selected for through periodically prolonged flooding in the Basin. Outside the episodically inundated zone, along the feeder creeks and the Santa Ana River, there was a greater diversity in the canopy composition and heavier low plant cover (Table 3). Shrubby riparian growth has been flooded out, and so was very locally distributed in the Basin and slightly more abundant along the tributaries. In places along the basin edge there are dense, monotypic stands of the non-native giant reed (Arundo donax). This noxious species has invaded riparian woodlands over most of southern California at the expense of the productive native habitats and dependant wildlife.

THE BREEDING BIRDS

Of the 221 species of birds identified along the Santa Margarita River, 97 species were most closely associated with riparian communities and 53 species were common in both riparian and upland situations. Seventy-five species of birds were detected breeding on the 8 plots in riparian habitats in 1982 and 1983. Bird densities, extrapolated to pairs per 100 acres (40.5 ha), varied from 477 pairs to 935 pairs per 100 acres (40.5 ha) in 1982. The 1982 data are displayed in Table 4. Winter bird and 1983 data are available elsewhere (Zemba 1984). Although not the focus of this paper, it should be noted that the riparian habitat studied was extremely important to migrant passerines and wintering species in general with 94 species detected on the 8 plots.

Thirteen species of breeding birds occurred on every plot and comprised 61.5% of all birds detected breeding on the plots. The highest diversity on a single plot was of 50 breeding species and was documented on the plot with the greatest diversity of available habitats within willow woodland. The relationships were not simple for some species but habitat structure and composition clearly influenced the presence of many birds, some examples of which follow. The song sparrow (Melospiza melodia) was nearly three times as abundant as the next most commonly encountered species. Nesting habitat for this species is comprised of low ground cover plants that were abundantly available somewhere on every plot. The abundance of house wrens (Troglodytes aedon) was directly proportionate to the abundance of trees large enough to provide suitable cavities and snags. Consequently, they were regular in mixed woodlands and an

Table 3. Composition of the woodland vegetation within the Prado Basin and along the feeder watercourses.
Adapted from Zembal et al 1985.

Trees per acre

	Prado Basin	Santa Ana River	Chino Creek	Temescal Creek	Mill Creek
<u>Salix gooddingii</u>	677	526	625	570	525
<u>Salix lasiolepis</u>	130	316	195	465	-
<u>Salix laevigata</u>	-	20	125	-	-
<u>Populus fremontii</u>	1	6	-	-	-
<u>Sambucus mexicana</u>	-	6	-	-	-
<u>Ricinus communis</u>	2	-	-	-	-
Standing snags	18	302	550	5	5
Totals	828	1,176	1,495	1,040	530

Low ground cover (%)

	Prado Basin	Santa Ana River	Chino Creek	Temescal Creek	Mill Creek
Litter	52.3	46.3	3.8	16.5	50.1
Deadfall	14.7	13.1	12.8	24.7	3.8
Plant Cover	8.1	34.4	77.7	41.3	5.1
Total low cover	75.1	93.8	94.3	82.5	59.0
Bare ground	24.9	6.2	5.7	17.5	41.0

Table 4. Count and density per 100 acres of breeding birds on 8 plots in riparian habitats along the Santa Margarita River, spring 1982. Adapted from Zembal 1989. Abbreviations and corresponding bird names are presented in Appendix 2.

SP.	DIKE		SHOOTING RANGE		DELUZ CREEK		RAINBOW CREEK		DELUZ CROSSING		SANDIA CREEK		SANDIA CONFLUENCE		TOTAL DENSITY		AVERAGE PLOT DENSITY	
	cnt.	den.	cnt.	den.	cnt.	den.	cnt.	den.	cnt.	den.	cnt.	den.	cnt.	den.	den.	den.	den.	den.
SOSP	75.0	286	69.0	233	36.5	137	14.0	45	21.0	87	36.0	111	43.0	134	66.0	210	1243	155
HOWR	+	0	0.0	0	38.0	143	24.0	78	6.0	25	36.0	111	23.0	72	2.0	6	435	73
COYE	43.0	164	30.0	101	3.0	11	11.0	36	0.0	0	6.0	18	14.0	44	5.0	16	390	56
RSTO	12.0	46	8.0	27	9.0	34	6.5	21	9.0	37	14.5	45	12.0	38	9.5	30	278	35
BEWR	8.0	31	3.0	10	11.0	41	1.5	5	12.5	52	2.5	8	5.0	16	8.0	25	188	24
YEWA	8.0	31	4.0	14	10.0	38	0.0	0	3.5	15	4.5	14	1.0	3	21.0	67	182	26
BUSH	6.0	23	4.0	14	6.0	23	6.0	19	8.0	33	2.0	6	13.0	41	5.5	18	177	22
BHGR	6.0	23	1.0	3	9.0	34	3.0	10	9.0	37	5.5	17	7.0	22	8.0	25	171	21
LEGO	1.0	4	+	0	+	0	5.0	16	6.0	25	10.5	32	20.0	63	7.0	22	162	27
OCWA	2.0	8	2.0	7	6.0	23	6.0	19	6.0	25	9.5	29	11.0	34	4.5	14	159	20
ANHU	2.0	8	3.0	10	10.0	38	+	0	+	0	8.0	25	14.0	44	3.0	10	135	23
HUVI	3.0	11	1.5	5	4.0	15	6.0	19	3.5	15	7.5	23	10.0	31	4.0	13	132	17
WREN	7.0	27	2.0	7	+	0	2.5	8	11.0	46	0.5	1	6.0	19	7.0	22	130	19
YBCH	8.0	31	6.5	22	3.0	11	1.0	3	5.0	21	0.0	0	0.5	2	6.0	19	109	16
MODO	3.0	11	9.0	30	0.0	0	6.0	19	6.0	25	+	0	1.0	3	5.0	16	104	17
BHCO	5.0	19	4.0	14	5.0	19	3.0	10	3.0	12	1.0	3	5.0	16	3.5	11	104	13
AMGO	15.0	57	12.0	41	+	0	0.0	0	0.0	0	0.0	0	1.0	3	0.0	0	101	34
ATFL	0.0	0	0.0	0	3.5	13	5.5	18	3.5	15	4.5	14	10.0	31	1.0	3	94	16
PLTI	+	0	0.0	0	3.0	11	5.0	16	3.5	15	1.0	3	11.0	34	4.5	14	93	16
BRTO	+	0	1.5	5	+	0	2.5	8	6.0	25	7.5	23	10.0	31	0.0	0	92	18
BCHU	1.0	4	1.0	3	3.0	11	4.0	13	3.0	12	2.5	8	5.0	16	5.0	16	83	10
NUMO	0.5	2	0.0	0	7.0	26	3.0	10	2.0	8	0.5	1	7.0	22	3.0	10	79	11
WUPE	1.0	4	0.0	0	0.0	0	2.0	6	3.0	12	6.0	18	9.0	28	3.5	11	79	13
DOWO	1.0	4	2.0	7	10.5	39	0.0	0	1.0	4	0.0	0	0.0	0	3.0	10	64	13
SCJA	0.0	0	0.0	0	+	0	5.0	16	3.5	15	1.0	3	4.0	13	+	0	47	12
EUST	0.0	0	0.0	0	4.0	15	6.0	19	0.0	0	0.0	0	0.0	0	0.0	0	43	14
NOFL	1.0	4	0.0	0	2.0	8	2.0	6	1.5	6	3.0	9	2.0	6	1.0	3	42	6
RWBL	+	0	11.0	37	1.0	4	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	41	21
SWTH	4.0	15	0.5	2	+	0	+	0	+	0	1.0	3	4.5	14	1.0	3	37	8
WEFL	0.5	2	0.0	0	4.0	15	+	0	0.0	0	2.0	6	4.0	13	+	0	33	8
COHU	3.0	11	1.0	3	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	2.0	6	31	8
BEVI	3.0	11	3.0	10	0.0	0	0.0	0	1.0	4	0.0	0	0.0	0	+	0	31	6
NOOR	1.0	4	2.0	7	0.0	0	2.0	6	1.5	6	0.0	0	2.5	8	+	0	28	5
CAQU	1.0	4	1.0	3	0.0	0	1.0	3	1.0	4	1.5	5	3.0	9	+	0	27	7
ACWO	0.0	0	0.0	0	3.0	11	2.0	6	1.0	4	+	0	2.0	6	0.0	0	23	5
CATH	0.5	2	0.0	0	0.0	0	1.5	5	3.0	12	0.5	1	1.0	3	0.0	0	21	4
BLPH	2.0	8	1.0	3	+	0	0.0	0	+	0	1.5	5	1.0	3	0.5	2	18	9
AMCO	4.0	15	1.0	3	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	13	4
AMKE	0.0	0	0.0	0	1.0	4	1.5	5	1.0	4	0.0	0	0.0	0	0.0	0	13	4

TABLE 4 (Cont.)
DIKE

SP.	cnt.	den.	SHOOTING RANGE	DELUZ CONFLUENCE	DELUZ CREEK	RAINBOW CREEK	DELUZ CROSSING	SANDIA CREEK	SANDIA CONFLUENCE	TOTAL DENSITY	AVERAGE PLOT DENSITY
	0.0	0	cnt. den.	cnt. den.	cnt. den.	cnt. den.	cnt. den.	cnt. den.	cnt. den.	13	13
NRWS	0.0	0	0.0 0	0.0 0	0.0 0	0.0 0	0.5 1	0.0 0	0.0 0	13	4
PHAI	0.0	0	0.0 0	0.0 0	0.0 3	0.0 0	0	3.0 9	0.0 0	13	3
RSHA	0.5	2	0.0 0	1.0 4	0.0 0	0	0	1.0 3	1.0 3	12	3
RTHA	0.0	0	0.0 0	0.0 0	1.0 3	0.5 2	1.0 3	1.0 3	0.0 0	11	3
COMO	3.0	11	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	11	11
BNST	3.0	11	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	11	11
CBOW	0.0	0	0.0 0	1.0 4	2.0 6	0.0 0	0.0 0	0.0 0	0.0 0	10	5
BSKI	1.0	4	1.0 3	0.5 2	0.0 0	0	0.0 0	0.0 0	0.0 0	9	3
BEKI	0.0	0	0.0 0	0.0 0	0.0 0	1.0 4	1.0 3	0.5 2	0	9	3
GRHE	2.0	8	0	0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	8	8
KILL	1.0	4	0.0 0	0.0 0	1.0 3	0.0 0	0.0 0	0.0 0	0	7	4
COHA	0.0	0	0.0 0	0.0 0	1.0 3	0.0 0	0.0 0	1.0 3	0.0 0	6	3
WSOW	0.0	0	0.0 0	0	1.0 3	0.0 0	1.0 3	0.0 0	0.0 0	6	3
COPO	0.0	0	0.0 0	0.0 0	1.0 3	0.0 0	1.0 3	0.0 0	0.0 0	6	3
WEME	1.5	6	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	6	6
HOFI	0.0	0	0.0 0	0.0 0	1.0 3	0	0.0 0	1.0 3	0.0 0	6	3
CITE	1.0	4	0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	4	4
MALL	1.0	4	0	0.0 0	0	0.0 0	0.0 0	0.0 0	0	4	4
AMAV	1.0	4	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	4	4
AMCR	1.0	4	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	4	4
CORA	0.0	0	0.0 0	1.0 4	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	4	4
BLGR	1.0	4	0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	4	4
NOHA	0.0	0	1.0 3	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	3	3
VIRA	0.0	0	1.0 3	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	3	3
WJFL	0	0	1.0 3	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	3	3
ROWR	0.0	0	0.0 0	0.0 0	0.0 0	0.0 0	1.0 3	0.0 0	0.0 0	3	3
HOOR	0.0	0	0	0.0 0	0.0 0	0.0 0	0.0 0	1.0 3	0	3	3
LAGO	0.0	0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	1.0 3	0.0 0	3	3
WAVI	0.5	2	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	2	2
CAWR	0.0	0	0.0 0	0.0 0	0.0 0	0.0 0	0.5 1	0.0 0	0.0 0	1	1
PBGR	0	0	0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0	0
REDH	0	0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0	0
CLSW	0.0	0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0	0
LABU	0.0	0	0.0 0	0.0 0	0.0 0	0.0 0	0	0.0 0	0.0 0	0	0
RCSP	0.0	0	0.0 0	0.0 0	0.0 0	0	0.0 0	0.0 0	0.0 0	0	0

Totals:

Count	254	188	196	147.5	147.5	147.5	183.5	275	199.5		
Density	935	635	736	477	477	612	565	859	635		
Species	50	37	37	40	40	40	40	41	38	Species Grand Total: 74	

Sp.: Species common name; see Appendix 2 for key to these standardized abbreviations. cnt.: actual count on the plot.

den.: Density per 100 acres (40.5 ha). Average density is only for the plots where at least half of a territory of the species was found. +: species occurred in density of less than 0.5 pair per plot.

indicator species of the gallery stage of willow woodland, where they reached their greatest abundance. Common yellowthroats (Geothlypis trichas) nested in abundance in marsh pockets but to be present required only low cover for nest concealment, coupled with shrubby patches and so, were fairly ubiquitous. Yellow warblers (Dendroica petechia) were territorial in tall willow and cottonwood stands. Bushtits (Psaltiriparus minimus) nested on the edges of stands of trees. Lesser goldfinches (Carduelis psaltria) nested in shrubby riparian thickets where willows were the dominant trees but nested higher in broad-leaved trees in mixed woodlands, in sycamores and cottonwoods. American goldfinches (Carduelis tristis) nested in the willows in willow woodlands but were absent as nesters in mixed woodlands. Hutton's vireos (Vireo huttoni) are known for their affinity for oaks and were also regular in pure willow woodlands where specimen trees were available. Wrentits (Chamaea fasciata) and California thrashers (Toxostoma redivivum), more commonly associated with shrublands, were regular inhabitants of shrubby riparian growth in the floodplain. Least Bell's vireos and yellow-breasted chats (Icteria virens) nested mostly in shrubby understory, associated with willow stands. The downy woodpeckers (Picoides pubescens) were indicators of gallery willow stands and were replaced as the principle cavity excavator and nester in mixed woodlands by the Nuttall's woodpecker (Picoides nuttallii).

Several species observed nesting along the Santa Margarita River are mostly associated with riparian habitats and are considered very rare or extirpated as nesters in southern California. Most notable among these are the least Bell's vireo, willow

flycatcher (Empidonax traillii), yellow-breasted chat, swainson's thrush (Catharus ustulatus), warbling vireo (Vireo gilvus), yellow warbler, belted kingfisher (Ceryle alcyon), long-eared owl (Asio otus), northern harrier (Circus cyaneus), and redhead (Aythya americana).

Of the 178 species of birds identified in the Prado Basin and environs, 100 species were most closely associated with riparian and open water habitats and 49 species were regular in upland and riparian situations. Forty-seven species were detected on the 8 breeding bird plots. Bird densities, extrapolated to territories per 100 acres (40.5 ha), varied from 746 to 1,013 pairs per 100 acres (40.5 ha) of similar habitat. Shrubby understory was most abundant on 4 of these willow woodland plots with associated bird densities and diversity of 904 - 1,013 territories per 100 acres (40.5 ha) and 28 - 34 species. The other 4 plots were relatively lacking of shrubby understory with associated bird densities and diversity of 746 - 904 territories per 100 acres (40.5 ha) and 21 - 24 breeding species. The Prado Basin is also extremely important for wintering species, as well.

Thirteen species of breeding birds were present on every plot. Nine of these species accounted for 81.8% of the total birds counted on all plots (Table 5).

Seven of the species breeding in the Prado Basin are considered rare or extremely locally distributed in California. Notable among these were the least Bell's vireo, yellow-billed cuckoo (Coccyzus americanus), willow flycatcher, yellow-breasted chat, Swainson's thrush, yellow warbler, long-eared owl, and northern pintail (Anas acuta).

Seven species of breeding birds were

Table 5. Breeding Bird Censuses on 8 Plots in the Prado Basin, 1987.
Adapted from Zembal 1988.

Bird Species ¹	Bird Territories Per Plot ²					TCO	RO	ORO	TOTALS
	RU	TCU	WMCU	EMCU	OBO/U				
SOSP	28.5	34	38	36	46.5	33.5	32	36.5	285
YBCH	14.5	4	4	4.5	1	---	---	3	31
RSTO	13	15.5	12.5	13	8	5.5	9.5	11.5	88.5
AMGO	12	9	10	9	7	3	2	5.5	57.5
COYE	11.5	8	16	16.5	13	9	2	5	81
BHCO	7	9	6.5	8	8	7	10	8	63.5
MODO	6.5	4.5	1.5	3.5	1	3	2.5	2	24.5
BUSH	6	9	8	8	3	2.5	4	3	43.5
BHGR	5.5	6	5	4.5	8	4	5.5	4	42.5
LABU	3.5	+	---	---	---	---	+	---	3.5
BLGR	3	1	0.5	0.5	---	---	---	0.5	5.5
BCHU	3	1	1	---	---	+	+	---	5
BEWR	2.5	4.5	1	1	3	+	0.5	2.5	15
NOOR	2	4	1	1	1	2.5	2	1.5	15
BRTO	2	0.5	+	---	---	---	---	---	2.5
AMCR	1.5	2	4	3	2.5	1.5	2	2	18.5
LEGO	1.5	---	---	---	---	---	---	---	1.5
ANHU	1	2	1	1.5	+	+	---	0.5	6
CATH	1	1	1	1	---	---	---	---	4
HOWR	1	5.5	9	3	7	13	23	13.5	75
CGDO	1	0.5	---	---	---	---	---	---	1.5
ATFL	1	---	---	1	---	---	---	---	2
NOFL	1	1.5	+	0.5	---	1	+	---	4
ROAD	1	---	---	---	---	---	---	---	1
PLTI	1	0.5	+	---	---	0.5	+	+	2
DOWO	1	2	2	2	1.5	2.5	1	2	14
YEWA	0.5	2	1.5	---	---	3	+	0.5	7.5
LBVI	0.5	+	3	+	---	---	---	---	3.5
HOFI	0.5	0.5	---	---	---	---	---	---	1
RSHA	0.5	---	+	+	0.5	0.5	0.5	+	2
GBHE	0.5	---	+	---	1	---	0.5	+	2
WEFL	+	2	---	---	---	---	+	---	2
BSKI	+	+	+	+	---	---	---	---	---
SWTH	+	1.5	0.5	1.5	---	---	---	0.5	4
OCWA	---	1	---	0.5	---	---	---	---	1.5
RWBL	---	0.5	---	1	2	0.5	2	+	6
WIFL	---	+	---	---	---	---	---	---	---
YBCU	---	+	---	---	---	---	---	---	---
RTHA	---	+	0.5	---	---	+	0.5	---	1
RNPH	---	---	+	+	---	---	---	---	---
BAOW	---	---	+	+	---	---	---	---	---
GTGR	---	---	---	+	---	---	---	---	---

Table 5. Breeding Bird Censuses on 8 Plots in the Prado Basin, 1987 (Continued).

Bird	Bird Territories Per Plot ²								
Species ¹	RU	TCU	WMCU	EMCU	OBU/U	TCO	RO	ORO	TOTALS
MAWR	---	---	---	---	6	---	---	---	6
SCOW	---	---	---	---	0.5	---	---	---	0.5
AMKE	---	---	---	---	+	---	---	---	---
HUVI	---	---	---	---	---	+	---	---	---
HOOR	---	---	---	---	---	---	+	---	---
TOTALS	135	132.5	127.5	120.5	120.5	92.5	99.5	102	930
#/100ac. ³	1013	994	956	904	904	833	746	765	
Species ⁴	34	34	30	28	21	22	24	22	

¹ See Appendix 2 for key to these standardized abbreviations of bird common names.

² Plot abbreviations: RU= Understory (Raahaugge's), TCU= Temescal Creek Understory, WMCU= West Mill Creek Understory, EMCU= East Mill Creek Understory, OBO/U Oil Berm Overstory/ Understory, TCO= Temescal Creek Overstory, RO= Overstory (Raahaugge's), ORO= Oil Rig Overstory. All overstory plots had some shrubby understory and some additionally had a mix of herbaceous understory and dead fall. The understory plots were selected for their high relative abundance of shrubby understory. The "OBO/U" plot was the only one with a high percentage of freshwater reed understory.

³ Projected number of territories/ 100 acres (40.5 ha) for each plot.

⁴ Number of bird species recorded in plot.

among the thirteen most common in both the Prado Basin and Santa Margarita River valley. These 7 species were the most widespread and abundant in the riparian habitat examined and included the song sparrow, common yellowthroat, rufous-sided towhee (Pipilo erythrophthalmus), Bewick's wren (Thryomanes bewickii), bushtit, black-headed grosbeak (Pheucticus

melanocephalus), and brown-headed cowbird (Molothrus ater).

CONCLUDING REMARKS

The high productivity and extent of riparian habitat along the Santa Margarita River, Prado Basin, and environs is reflected in the abundance and diversity of breeding birds. Review

Figure 1. Breeding Birds of Santa Margarita River, Prado Basin, and Other Locales

Data from Other Locales from Amer. Birds

of the available data in "American Birds" up to 1987 reveals that the abundance and diversity of breeding birds is unrivalled in southern California, and only exceptionally in similar wetlands (Figure 1). The greater structural and compositional diversity of the habitats available along the Santa Margarita River is reflected in the high diversity encountered there. The unbroken vastness of the Prado woodlands may account for the incredible abundance of breeding birds there and certainly is responsible for the presence of the yellow-billed cuckoo (Gaines and Laymon 1984).

The overall bird use of the study areas reflects the rarity of such riparian situations as indicated by the rarity of many of the avian inhabitants. Thirty-four species of birds documented in the Prado Basin are rare to very rare and have warranted special status (Zemba

1989); 5 of these species are state and/or federally listed and an additional 4 species are candidates for federal listing. The remainder were included on various "watch lists" (Remsen 1978, Tate and Tate 1982, and U.S. Fish and Wildlife Service 1982) and will be the future candidates for listing and listed species, should the quantity and quality of wetlands be allowed to continue to diminish. There were 42 species of birds warranting special status found along the Santa Margarita River (including the river mouth habitats) including 6 listed species and 4 candidates (Zemba 1984). Several of these species are dependent upon other habitats, a few heavily so, but all rely to some extent on wetlands, particularly riparian. Recent estimates place the loss of southern California's floodplain riparian habitat as high as 95 - 97% (Faber et al. 1989).

As the human population increases

in southern California, conversion of the remaining open spaces to other purposes will lead to continued pressure for additional encroachment on our floodplains. The clamor for multiple use of these lands could perpetuate the trend of loss and degradation of riparian habitat in southern California. Increased knowledge of the high wildlife usage and other values associated with these habitats is essential in reversing this trend. Equally as important is the dissemination of such knowledge. The challenge will be in convincing people that the only acceptable uses of floodplains are minimally destructive ones because the primary functions of such lands are best performed as naturally as possible. With such an approach the wonderful wildlife legacy embodied in the plants and animals of southern California's riparian forests could be widely protected, restored, and thereby perpetuated.

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APPENDIX 1. BIRD PLOT NICKNAMES AND CORRESPONDING HABITAT-ORIENTED TITLES (SEE AMERICAN BIRDS 1984 POPULATION STUDIES ISSUE).

Dike Plot is Willow Woodland With Ponded and Channeled Water.

Shooting Range Plot is Tall Willow Woodland With Dense Riparian Understory.

Deluz Confluence Plot is Tall Willow Woodland With Patchy Low Ground Cover.

Deluz Creek Plot is Open Creekside Mixed Woodland.

Deluz Road Crossing Plot is Narrow Riverine Band of Willow and Mixed Woodland.

Sandia Creek Plot is Narrow Creekside Band of Mixed Riparian Woodland.

Sandia Confluence Plot is Riverine Willow Woodland With Scattered Cottonwoods.

Rainbow Creek Plot is Riverine and Creekside Riparian Woodlands.

APPENDIX 2. ABBREVIATIONS AND CORRESPONDING BIRD COMMON NAMES.

ACWO=acorn woodpecker; AMAV=American avocet; AMCO=American coot;
AMCR=American crow; AMGO=American goldfinch; AMKE=American kestrel
ANHU=Anna's hummingbird; ATFL=ash-throated flycatcher; BEVI=Bell's vireo;
BEKI=belted kingfisher; BEWR=Bewick's wren; BCHU=black-chinned hummingbird;
BHGR=black-headed grosbeak; BNST=black-necked stilt; BLPH=black phoebe; BSKI=black-shouldered kite; BLGR=blue grosbeak; BHCO=brown-headed cowbird; BRTO=brown towhee (now CA towhee); BUSH=bushtit; CAQU=California quail; CATH=California thrasher;
CAWR=canyon wren; CITE=cinnamon teal; CLSW=cliff swallow; CBOW=common barn owl;
COMO=common moorhen; COPO=common poorwill; CORA=common raven;
COYE=common yellowthroat; COHA=Cooper's hawk; COHU=Costa's hummingbird;
DOWO=downy woodpecker; EUST=European starling; GRHE=green-backed heron;
HOOR=hooded oriole; HOFI=house finch; HOWR=house wren; HUVI=Hutton's vireo;
KILL=killdeer; LEGO=lesser goldfinch; LAGO=Lawrence's goldfinch; LABU=lazuli bunting;
MALL=mallard; MODO=mourning dove; NOFL=northern flicker; NOHA=northern harrier;
NOOR=northern oriole; NRWS=northern rough-winged swallow; NUWO=Nuttall's woodpecker;
OCWA=orange-crowned warbler; PHAI=phainopepla; PBGR=pied-billed grebe;
PLTI=plain titmouse; REDH=redhead; RSHA=red-shouldered hawk; RTHA=red-tailed hawk;
RWBL=red-winged blackbird; ROWR=rock wren; RCSP=rufous-crowned sparrow;
RSTO=rufous-sided towhee; SCJA=scrub jay; SOSP=song sparrow; SWTH=Swainson's thrush;
VIRA=Virginia rail; WAVI=warbling vireo; WEFL=western flycatcher; WEME=western meadowlark;
WWPE=western wood pewee; WSOW=western screech owl; WIFL=willow flycatcher;
WREN=wrentit; YBCH=yellow-breasted chat; YEWA=yellow warbler.

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