Northern Sierra Madre Occidental and Its Apachian Outliers: A Neglected Center of Biodiversity[1]

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Abstract.—The Apachian-Madrean region is a zone of confluence and geographic termini of species and floras from the north and the south. Lower and intermediate elevations support many taxa of tropical plants and animals that are at their northernmost limits. It is a region of tremendous habitat diversity and species richness. Much of the region remains little known, and quantified data are scarce. This report offers brief synopses on the insect fauna, ichthyofauna, herpetofauna, avifauna, mammals, and vegetation and flora of the region. The vascular plant flora is estimated to include approximately 4,000 species, although endemism is not particularly high. A partial listing of endemic plants numbers more than 250 taxa. Likewise there are approximately 250 wild relatives of domesticated crop plants. Land race diversity of native crops is richer than in any other American region north of the tropics. A brief economic assessment, descriptions of environmental threats and conservation measures are included.

INTRODUCTION

In the rush to save the rainforest, other biologically rich natural areas have been neglected. The Sierra Madre Occidental of Mexico and its montane outliers in the southwestern United States constitute such a region. While recognized by the International Union for the Conservation of Nature (IUCN) as one of the global megacenters of plant diversity (Felger et al. in press), this region has received far less critical attention from biogeographers and conservationists than it deserves. The purpose of this work is to direct attention to the unusual and diverse biota of this region and to describe the threats to this diversity.

The Sierra Madre Occidental forms a zone of essentially contiguous montane woodland that stretches from southern Mexico nearly to the international border of the United States. Pacific tropical lowlands fringe the greater portion of the western flank while temperate highlands to the east exert a profound continental influence on the inland portions. Conventional classifications of biotic communities necessarily define regions by virtue of their similarities. In contrast, we are more interested in calling attention to a region that is distinguished by a remarkable heterogeneity of habitats. As such, there are no convenient biotic or, for that matter, political or geographic boundaries that allow us to define the region.

We focus on a 180,000 km^2 area situated largely in northwest Mexico, as far south as the Sinaloa border with Sonora and Chihuahua, and northward along the continental divide, roughly at the Sonora-Chihuahua border, to southwestern New Mexico and southeastern Arizona in the United States (fig. 1). The area is about 300 km from east to west (approximately 111 to 107 degrees west longitude), centered on the continental divide. It is 600 km long, spanning an area from

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the mountains of southeastern Arizona and southwestern New Mexico in the United States to the Río Mayo, Río Fuerte and Río Conchos drainages in Sonora and Chihuahua, Mexico (approximately 25 to 32 degrees north latitude). Elevations in this region range from 400 m to more than 3000 m on the highest peaks.

GEOGRAPHY

The region includes two floristic districts of the Madrean province centered on the Sierra Madre Occidental of northern Mexico. This district includes the sky-island ranges such as the Animas, Baboquivari, Chiricahua, Galiuro, Huachuca, Santa Rita, Santa Catalina, and Pinaleño mountains of the United States and the Sierra de los Ajos, Azul, Buenos Aires, Cananea, la Purica, and Mariquita of Mexico, among others. The Apachian district extends northward to the Mogollon Rim in the southwestern United States. Adjacent areas of mid-elevation and sky island peaks in northwestern Mexico form the southern portion of this district which merges with the northern reaches of the Madrean district. Included is the Deming Bridge in the vicinity of the Chiricahua and Animas mountains which is the lowest place on the continental divide between Mexico and Canada. The Madrean district is characterized by the cordilleran flora which begins at the northernmost edge of the Sierra Madre Occidental proper, lying

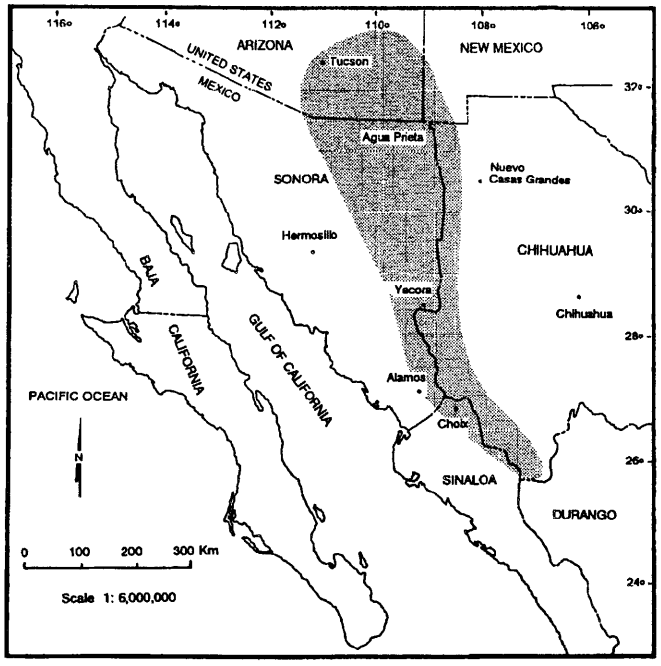

Figure 1.—Northern Sierra Madre Occidental and southern Apachian/Sky Island complex in southwestern North America.

about 150 km south of the United States border. This district extends southward in western Mexico and eventually merges with tropical Mesoamerican regions.

Based upon a land classification study using climatic, geomorphological, and lithological features, Cuanalo et al. (1989) placed the Mexico portion of the Apachian/Madrean Region in the Sierra Madre Occidental Terrestrial Province. Of the 33 subregions distributed in the 10 regions of this province, eight are found in the area covered by the Madrean Region of southwestern North America. They are distinctive enough to warrant special classification: (La1) Arroyo Santísimo; (La6) western portion of the Sierra Madre Occidental; (Lb3) Santiago Papasquiaro; (Lc7) Barranca del Cobre; (Lc8) Yepachic; Tecoragui; (Lf1) Cananea; (Lg2) Nuri; and (Lh5) Chuichupa.

The region is drained primarily by the Río Yaqui, Río Mayo, and Río Fuerte watersheds in the west, and to the east by the Río Bravo (Río Grande) and Río Conchos. The northern outlier archipelago in southeastern Arizona falls largely within the Gila River drainage. Volcanic tuff and Laramide limestones dominate the surface geology.

Precipitation is generally proportional to elevation in the region.Precipitation ranges from roughly 300 to more than 1200 mm/year on the highest peaks, with a summer monsoon predominating in seasonal contribution. The southern portions of the region, particularly at low to mid-elevations, are essentially frost-free, but as one moves northward and upward in elevation, freezing temperatures become common. Moderate to severe winter freezing occurs at the higher elevations.

BIOLOGICAL SIGNIFICANCE

The complex topography and the extreme elevational gradients of the sky island ranges and the northern Sierra Madre Occidental result in a rich flora and fauna (Toledo & Ordóñez 1993). However, it is not merely the individual biotic communities that make the region remarkable, for most of these communities can be found elsewhere and often more extensively. Spanning several degrees of latitude, the character of the region makes for unusual and striking assemblages of habitats. This effect is particularly remarkable for the tropical and subtropical western flanks of the range. The Sierra Madre Occidental acts as a corridor for many taxa. Ani-

mals and plants occur here that are more commonly associated with the neotropics than with areas relatively close to the United States border. Species mingle which would otherwise be separated by considerable distance, both geographically and biotically. For example, in canyons of the Río Satachic, near Nacori Chico in northeastern Sonora, maples grow alongside palms and organpipe cacti. In the southern reaches of the region, oaks, pines and alders are host to epiphytic orchids and bromeliads.

With such assemblages of organisms—tropical, temperate, xeric —climatic extremes exert a profound influence, perhaps more often and of a greater magnitude than in more homogeneous communities. Catastrophic frosts occur approximately every ten to fifteen years in portions of the region (Bowers 1980). These events can have devastating effects on animal and plant populations. Areas where subtropical plants show repeated and profound effects of frost are common towards the northern part of the region, and this is visible both locally and on a gross scale. Within a short distance, from cliff-face to arroyo bottom, plant stature and size may change drastically. Pruned by winter frost, shrunken by drought, certain plant species that become formidable trees in tropical lowlands are merely small shrubs in northern Sonora and southern Arizona.

During years of unfavorable weather, frost- or drought-sensitive species may maintain themselves as residual populations in various microhabitats, re-invading neighboring zones during more equitable periods. However, local extinctions during recent times have been well documented for certain groups of organisms, particularly insects (see Bailowitz & Brock 1991). It seems that the generally low level of endemism in most taxa of the region is, in many cases, partially a by-product of a fauna and flora that is in continual ebb and flow between more equitable areas to the south and uncertain habitats to the north. It is not correct to call all these populations "relicts," however, for the more mobile organisms may repeatedly establish, die-off and re-establish themselves. Populations stranded in refugia since the Pleistocene, such as the Mt. Graham red squirrel and the *Tilia* trees at Basaseachic Falls, are indicative of a very different process.

Even so, other phenomena in this region are ultimately unrelated to climate but have effects that are similar and remarkable. On the western side of the sierras, particularly in east-central Sonora, hydrothermally-altered, acidic soils support oaks and pines surrounded by tropical deciduous forest (Goldberg 1982, Búrquez et al. 1992). So well delineated are these zones that one can move from one biotic community to another in but a few steps. These pine-oak or oak communities vary in size from less than one to many hectares in area and are of the same elevation as the surrounding legume-dominated forest. Though they may be several kilometers from the main body of madrean oak woodland, they often have an impressive complement of animals reliant on oaks or pines.

Many species are at the very limit of their ranges within the region. This effect is more striking for tropical organisms than for temperate ones. For while temperate climes and their inhabitants can be found at higher elevations far south of the region discussed here, the tropics of the Americas, under the yoke of winter frost and summer drought, exhaust themselves on the western flank of the northern Sierra Madre Occidental. Consequently, while relatively few animals and plants encounter their southern limits within our region, many more are at their northernmost range here. This phenomenon involves a broad spectrum of organisms - moths as well as birds, trees as well as orchids.

VEGETATION AND FLORA

The evergreen woodlands and forests of the region were derived from more generalized Madro-Tertiary vegetation before the end of the Pleistocene (Axelrod 1979). Despite the commonality of species in genera such as *Pinus, Juniperus,* and *Quercus,* there are at least two distinct floristic assemblages of woodland species in the mid- to upper-elevations of the region (McLaughlin 1986). These allied but readily distinguishable floristic elements have been termed the Apachian, designating the northern horseshoe-shaped district rimming the northern Sierra Madre Occidental, but extending as far north as the Mogollon Rim; and the Madrean, designating the more seminal and tropical flora characteristic of the mountains between the Sierra Mohinora and the United States border (McLaughlin 1986, 1989).

Within these two districts, no less than eight physiognomic vegetation types can be found: montane evergreen forest; oak-coniferous (evergreen) woodland; tropical deciduous forest; oak savanna (the oaks mostly drought-deciduous); chaparral; short-grass prairie; subtropical thornscrub; and subtropical desert fringe (Brown 1982, Marshall 1957, Rzedowski 1978). A ninth physiog-

nomic vegetation type (which may be the counterpart of the oak savanna) is the barrancan oak woodland which forms a distinctive, narrow belt on the western slope of the Sierra Madre (Gentry 1942). Three of these types, montane evergreen forest, mixed evergreen woodland, and chaparral, are strongly associated with the Madro-Tertiary flora (Axelrod 1979). The Chiricahua Mountains, the Pinaleños and other northern sky islands have grassland and desert-margin at their bases and coniferous forest including spruce (*Picea*) and fir (*Abies*) at their highest elevations. Two major deserts, the Sonoran and Chihuahuan, reach their limits at the lower flanks of this montane region.

The flora of the Apachian/Madrean Region is the northwestern backbone of the two richest floras of mega-Mexico—which ranks as one of the three top mega-diversity centers of the world. We estimate that there are at least 4,000 vascular plant species within the confines of the region, although no regional summary is available. This estimate is based on the relative size of local and subregional floras (Table 1, also see McLaughlin 1995) and on floristic analyses by Rzedowski (1991, 1993). Most of these local floras fall short of the actual number of species present. For example, in spite of intense investigations over the last half century, the Río Mayo listing is probably only two-thirds to three-quarters complete (Phil Jenkins, pers. comm.). A partial listing of endemic plants in the region totals more than 250 taxa (Appendix 1). New species and infraspecific taxa continue to be discovered as the region becomes better-known botanically.

Table 1. Selected floras from the Apachian-Madrean Region

Area	No. of Species	Reference
Central Sierra Tarahumara	1900	Bye, unpublished
Río Mayo	2100	Martin, in prep.
Parque Nacional, Cascada de Basaseachic	750+	Spellenberg et al., in prep.
Río Bavispe	1100	White 1948
Sierra de los Ajos	est 1000	Fishbein et al., this volume
Chiricahua Mts	1200	Bennett et al., in prep.; Reeves 1976
Huachuca Mts	907	Bowers & McLaughlin, in prep.
Rincon Mts	959	Bowers & McLaughlin 1987
Pinaleño Mts.	786	McLaughlin 1993
Animas Mts	620	Wagner 1977

In terms of species richness per family, the most important families in the region are the Asteraceae (Compositae), Fabaceae (Leguminosae), Poaceae (Gramineae), and Euphorbiaceae. At least 18 families reach their northern limits—at least for western North America—within the region (Appendix 2). Tropical orchids represented by ten genera, including pseudobulb-forming species, also reach their northern limits here as do more than 120 other tropical genera (Appendix 2). Seventy-two percent of the trees of the region are tropical species at the northernmost limit of their range (Felger & Johnson 1995).

The Apachian-Madrean forests contain the largest remaining ponderosa pine ecosystem in southwestern North America that has not suffered fire suppression for most of the twentieth century. Douglas fir and pine tree-ring chronologies from several sites in northern Mexico contain the best known records of the El Niño-Southern Oscillation weather phenomenon (Cleaveland et al. 1992, Stahle & Cleaveland 1993). The El Niño-Southern Oscillation is the most important known cause of interannual variation in the global climate (Folland et al. 1990).

Local extinctions and the status of plants at risk in areas north of the international boundary are relatively well documented (e.g., Folk & Warren 1994), but the status of such plants in Sonora and Chihuahua remains virtually unknown. We can expect loss of biological diversity in the northern Sierra Madre Occidental, in some cases even before taxa are described. For example, the drowning of gigantic and biologically unexplored canyons by the Huites Dam in northeastern Sinaloa will undoubtedly result in extinctions.

USEFUL PLANTS

The region is the richest in wild congeners of domesticated crops of any area north of the Tropic of Cancer. Many of these plants are used and managed by indigenous peoples. Eighteen landraces of pre-Columbian crops occur in the area. Found in native fields, these include endemic domesticates of *Agave, Lepidium* and other mustards, *Hyptis*, and *Panicum*. There are at least 253 wild relatives of domesticated crop plants in the Apachian-Madrean Region (Appendix 3, also see Nabhan 1991, Nabhan & Felger 1985). We estimate

that the region supports 700 to 1000 useful wild plants, a few of which are listed in Appendix 4.

Because many communities of the Sierras have persisted in their traditional subsistence activities, much of their extensive botanical knowledge has remained intact. Ethnobotanical inquiries have suggested plant species with potential for economic development. The ethnobotanies of the Guarijio, Mayo, Mountain Pima, Sonoran mestizos and Tarahumara have been studied by Bye (1976), Gentry (1942, 1963), Laferrière (1991), Pennington (1963), Rea (in press), Reina-Guerrero (1993) and Yetman et al. (in prep). To date, we estimate that at least 350 food plants and 600 medicinal plants from this region have been documented ethnographically. These include a considerable number of species belonging to the Agavaceae, Asteraceae (Compositae), Cactaceae, Fabaceae (Leguminosae), Lamiaceae (Labiatae), and Solanaceae.

Important phytochemicals and other properties have been identified from analyses inspired by these ethnobotanies. For instance, the high papain content of *Jarilla chocola* (Tookey & Gentry 1969) has been established, as has the high soluble fiber content of *Hyptis, Plantago,* and *Salvia* seed mucilages (Brand et al. 1990). Other utilitarian categories, such as fish poisons used by the Tarahumara, have generated considerable interest (Pennington 1963). The toloache (*Datura lanosa*) of the western barrancas of Chihuahua has the highest content of hyoscine (scopolamine), an alkaloid in great demand by the pharmaceutical industry, of any Mexican species studied (Bye et al. 1991).

Among the regional floras in arid and semiarid southwestern North America, it is estimated that 18 percent of the species have been utilized by people for food and 20 percent for medicinal purposes (Baker et al. in prep., Felger & Nabhan 1978). About 10 percent of the edible species, or 1.8 percent of the flora, served as major food resources (Felger 1979). These estimates, based on compilation of known data, are in line with results from individual ethnobotanical studies (e.g. Bye 1976, 1985; Felger & Moser 1985; Gentry 1942, 1963; Laferrière 1991; Rea in press). For example, the Tarahumara utilized at least 220 species of plants for food. Their pharmacopoeia includes about 300 plant species (Bye 1985) of which 47 are collected and sold in the urban markets of northern Mexico (Bye 1986).

Several potentially important relatives of domesticated crops are endemic to the Sierras, yet the germplasm resources of the region remain undercollected. *Agave, Cucurbita, Phaseolus, Prunus,* and *Solanum* are well-represented in the region, with more than 50 species found here. At Nabogame (near Sierra Mohinora), Chihuahua, the northernmost population of teosinte is disjunct several hundred kilometers from the tropical range of these wild and weedy relatives of maize, where they infrequently introgress with cultivated corn (Doebley & Nabhan 1989). The 21 wild *Phaseolus* taxa in the Sierra Madre Occidental constitute a richer assemblage than found anywhere else north of the Tropic of Cancer (Nabhan 1990a). The maintenance of gene flow between wild and cultivated plants by Tarahumara agroecological practices, which include the management of nearby forest, may be responsible for the development of a productive scarlet runner bean that is adapted to high mountain areas with short growing seasons. In fact, the mosaic of wild montane vegetation and Indian fields has provided ideal settings for studying introgression between wild and domesticated *Capsicum, Cucurbita, Phaseolus,* and *Zea*.

MAMMALS

Approximately 104 mammal species are found in the Apachian district of the Sierra Madre Occidental. The mammalian fauna is a product of a combination of climatic and elevational factors with contributions from two large biogeographic areas. Within this region several species such as the long-tailed vole (*Microtus longicaudus*) and the red squirrel (*Tamasciuris hudsonicus,* as subsp. *grahamensis*) reach the southern limits of their distributions, while species like the Nayarit squirrel (*Sciuris nayaritensis*) and the painted spiny pocket mouse (*Liomys pictus*) reach their northern limits. Some northern species are replaced by southern ones in this area. For instance, the montane shrew (*Sorex monticolus*) of central Arizona is replaced by the Arizona shrew (*Sorex arizonae*) in the sky island complex and the long-eared myotis (*Myotis evotis*) is replaced by the southwestern myotis (*Myotis auriculus*).

This region also functions as a corridor for the continued northward and westward expansion of subtropical species like javelina (*Tayassu tajacu*), coati (*Nasua narica*), "Mexican" opossum (*Didelphis virginiana californicus*) and cotton rats (*Sigmodon* spp.). Recent reports of jaguar (*Panthera onca*) (Girmendonk 1994) indicate continued use of this area as a conduit for occasional northward movement of this animal. The status of the jaguarundi (*Felis yagouaroundi*) in the region is

more uncertain. Despite continuing reports of these animals there are still no specimens from Arizona, Sonora or Chihuahua (David Brown, pers. comm.).

Although bat species richness increases further south, our area is well represented with 29 species. Subtropical species include the funnel-eared bat (*Natalis*), naked-backed bat (*Pteronotus davyi*), mustached bat (*Pteronotus pernilli*) and ghost-faced bat (*Mormoops megalophylla*) which reach their northern limits here, while the silver-haired bat (*Lasionycteris noctivagans*) only reaches as far south as the Chiricahua Mountains. Nectar-feeding bats (*Leptonycteris* and *Chaeronycteris*) depend on the nectar and pollen of agaves and other plants in their annual migrations. Other bats take advantage of the area for hibernals or foraging during the tempered winter months.

The construction of dams, declining groundwater levels, clearcutting of forests, farming and grazing has had a profound effect on the mammals of the region. *Cynomys ludovicianus*, the black-tailed prairie dog, was extirpated in Arizona prior to 1940, largely as a result of efforts by ranchers (Hoffmeister 1986). This species still "occurs in large numbers in the Valle de Carretas and other areas in northern Chihuahua and Sonora. In fact their abundance can only be described as awesome, at least periodically" (David Brown, pers. comm.). Some small areas serve as refugia for threatened species such as the southern river otter (*Lutra longicaudis*). The fate of the Mexican wolf (*Canis lupus baileyi*), however, is not clear. This animal is now probably extirpated in Sonora and Chihuahua and reports of individuals in Arizona should be regarded with skepticism (David Brown, pers. comm.). If current trends in land use continue these animals, severely threatened in their natural habitat, will follow the fate of the region's extirpated grizzly bear (*Ursus arctos*).

AVIFAUNA

Approximately 260 to 295 breeding birds are found in the Madrean center and its Apachian outliers. This estimate includes breeding birds in both the valleys and mountains, concentrating on the northern and middle Sierra Madre Occidental, the archipelago of sky islands in the United States, and portions of biotic communities at the bases of montane zones such as tropical deciduous forest.

Over half of the bird species in North America, including Greenland, are found in the Chiricahua Mountains (Kunzman et al. in prep.). As in other groups, many of the bird species of the region are not limited to the northern Sierra Madre Occidental. Many birds of madrean habitats are also found in the southern and eastern sierras as well as lowland tropical areas. In the United States, mountains with oak or pine-oak woodland in southern Arizona, New Mexico and the Chisos Mountains of Texas include several famous locales for sighting madrean bird species. The avifauna of the area is rich. The Madrean region has not been well studied as a migration corridor. However, over a hundred species are known visitants and migrants and the adjacent Pacific lowlands provide a crucial link for various species of hummingbirds and other migrants to their breeding grounds in northwestern North America.

Despite the generally wide area over which madrean habitats can be found, the "middle" Sierra Madre Occidental (sensu Escalante et al. 1993) is a center of bird endemism in Mexico. While there are no endemic bird families in the region, there is endemism at the generic, specific and subspecific levels. At least thirteen bird species are endemic to the northern Sierra Madre Occidental. Four species—the thick-billed parrot (*Rhynchopsitta pachyrhyncha*), Beechy's or purplish-backed jay (*Cissilopha beechii*), tufted jay (*Cyanocorax dickeyi*) and Mexican chickadee (*Parus sclateri*)—reside predominantly within the region. Extensive areas of forest are home to "specialty" birds of the pine-oak regions such as the thick-billed parrot, Mexican spotted owl (*Strix occidentalis mexicanus*), Arizona woodpecker (*Dendrocopos arizonae*), snowy-bellied martin (*Progne dominicensis*), Mexican chickadee, red-faced warbler (*Cardellina rubrifrons*), painted and slate-throated redstarts (*Myioborus picta* and *M. minatus*) and black-headed siskin (*Spinus notatus*).

Several bird families of Eurasian origin encounter their southern limits of distribution either in the northern Sierra Madre or just south of our area—these include the Paridae (titmice and chickadees), Aegithalidae (bushtits), Sittidae (nuthatches), Laniidae (shrikes), and Alaudidae (larks). The northern limits of at least five southern families are found in the region or nearby—these include the Psittacidae (parrots), Cracidae (chachalacas), Momotidae (motmots), Tinamidae (tinamous) and Trogonidae (trogons) with over a dozen other families terminating just south of the area. The Sierra Madre Occidental is the probable center of radiation for jays, woodpeckers, wrens, and ground sparrows (*Melazone*).

Habitat loss is the single most important element affecting bird populations in the Sierra Madre Occidental. The pet trade and hunting are also detrimental, particularly where bird populations have already been compromised by destruction of natural areas. The magnificent imperial woodpecker (*Campephilius imperialis*), which once inhabited mature mountain forests from Sonora to Michoacán, is extinct. Like the ivory-billed woodpecker of the United States, imperial woodpeckers were primarily victims of habitat loss, although unlike the former, hunting by local peoples may have sealed its fate (David Brown, pers. comm.).

ICHTHYOFAUNA

The ichthyofauna of the region, while relatively low in numbers of species in comparison with streams to the east and north, has an interesting and complex biogeographic history. Distributions of fishes with northern affinities, such as the roundtail chub or *charalito aleta redonda* (*Gila robusta*), suckers (*matalotes*) of the *Catostomus insignis/bernardini/conchos* clade, Yaqui catfish or *bagre Yaqui* (*Ictalurus pricei*), longfin dace or *charalito aleta larga* (*Agosia chrysogaster*), and Mexican stoneroller (*Campostoma ornatum*), appear to have been derived, at least in part, through interbasin connections and fragmentations in large, north-south oriented structural troughs which are part of a southerly extension of the Basin and Range Physiographic Province (Hendrickson et al. 1980, Minckley et al. 1986).

The Sonora topminnow or *guatopote de Sonora* (*Poeciliopsis occidentalis*), with southern affinities, has a distribution very similar to that of the longfin dace, ranging from the Río Fuerte to the Gila River. There is high diversity in this genus at lower elevations of the Fuerte and Mayo drainages, where a number of species and a complex of unisexual clones of hybrid origins have been the focus of many important studies in genetics, evolutionary and ecological theory, and conservation biology (e.g., Quattro et al. 1992, Vrijenhoek 1993, Leberg & Vrijenhoek 1994). These topminnows are among the most abundant fishes in low elevation streams where they often occur with the region's only other native freshwater fish of tropical origin, the Sinaloan cichlid or *mojarra de Sinaloa* (*Cichlasoma beani*).

Numerous species of the Yaqui, Mayo and Fuerte drainages were transferred across the continental divide when the headwaters of these rivers eroded into and captured former tributaries of the Rio Grande or endorheic (without outlet to the sea) drainages in Chihuahua (Minckley et al. 1986, Smith & Miller 1986). These include the Mexican stoneroller, beautiful shiner or *sardinita hermosa* (*Cyprinella formosa*), ornate minnow (*Codoma ornata*), Conchos chub or *charalito Conchos* (*Gila pulchra*) and undescribed relatives, Yaqui catfish, fleshylip sucker (*Catostomus leopoldi*), Cahita sucker (*C. cahita*), Rio Grande sucker or *matalote del Bravo* (*C.* [*Pantosteus*] *plebeius*), and an undescribed pupfish or *cachorito* (*Cyprinodon* sp.).

Several species that are found at high elevations apparently evolved by fragmentation of wide ancestral distributions. The presence of trouts in the region during ancient times is indicated by the occurrence of the Mexican golden trout or *trucha dorada Mexicana* (*Oncorhynchus chrysogaster*) in headwaters of the Ríos Fuerte and Culiacán (Needham & Gard 1964, Smith & Miller 6). This species is the apparent sister species of all other trout and salmon of the genus (Stearley & Smith 1993, Stearley 1992). Mountain suckers (subgenus *Pantosteus* of the genus *Catostomus*) likely have similar biogeographic histories (Smith 1992).

The Gila River basin of extreme northern Sonora, southern Arizona and western New Mexico is noteworthy for having a large number of endemic fishes, many of which are now endangered. Two trouts, both listed as threatened in the United States, Gila mountain-sucker (*Catastomus* [*Pantosteus*] *clarki*), and the Sonora sucker (*Catostomus insignis*) are endemic there, as are two small, endangered minnows, the loachminnow or *charalito locha* (*Rhinichthys cobitis*) and the spikedace or *charalito espina* (*Meda fulgida*). The basin also had a suite of Colorado River basin endemics (Minckley et al. 1986). Many of these once occurred in the mainstream Gila and San Pedro rivers of eastern and southeastern Arizona and northern Sonora which flow around the bases of sky islands such as the Pinaleño and Huachuca Mountains. All of these, Colorado squawfish or *salmon blanco* (*Ptychocheilus lucius*), bonytail chub or *charalito elegante* (*Gila elegans*), razorback sucker (*Xyrauchen texanus*), flannelmouth sucker (*Catostomus latipinnis*) and woundfin (*Plagopterus argentissimus*), have been extirpated in the Gila River basin and are critically endangered elsewhere (Minckley & Deacon 1991). Sonora topminnow and desert pupfish (*Cyprinodon macularius*), once both abundant in the middle and lower Gila River, remain as natural populations at only a few springs.

Unfortunately, the destruction of river basins of the western United States (Rinne & Minckley 1991, Moyle & Williams 1990) is being repeated in Mexico. The construction of dams, channeling and diversions is fragmenting populations of the primary freshwater fishes and threatening secondary marine fauna once common to the lower reaches of all major drainages to the Gulf of California. Non-native fishes, primarily sunfishes, catfishes and cichilds, invariably stocked in reservoirs. These exotics, which have had severe effects on native faunas elsewhere in western North America, have spread far from release sites. Some introduced species have hybridized with related native species so that genetically "pure" stock of certain species is now rare. Other threats include grazing and logging which can alter discharge, erosion and sedimentation in ways often detrimental to native fishes far downstream (Hendrickson & Minckley 1985). Unfortunately, lists of endangered, threatened, and extinct Mexican fishes (Williams et al. 1989, Contreras-Balderas & Lozano-Vilano 1994, Secretaría de Desarrollo Social 1994) are already long, are growing rapidly, and include many taxa from our region.

HERPETOFAUNA

This northern portion of the Sierra Madre Occidental, with associated tropical areas to the south and desert areas to the north, is rich in total herpetofaunal diversity although low in numbers of salamander species. There are at least 136 species of amphibians and reptiles in the region (3 salamanders, 29 frogs and toads, 11 turtles, 37 lizards, and 56 snakes) (Bogert & Oliver 1945, Flores-Villela 1993, Heringhi 1969, Stebbins 1985). Eight of those species are endemic to our region.

In this region several genera, a few families and a number of species are at the very northern limits of their distribution in the Americas. The northern casque-headed frog (*Pternohyla fodiens*), Mexican leaf frog (*Pachymedusa dacnicolor*), spiny-tailed iguana (*Ctenosaura hemilopha*), brown vine snake (*Oxybelis aeneus*) and *Boa constrictor* are representatives of genera found at their northern limits in this region. Other notable reptiles and amphibians that are at their northern limits here are the *pichicuate* (*Agkistrodon bilineatus*), green rat snake (*Elaphe triaspis*), spotted box turtle (*Terrapene nelsoni*), ridge-nosed rattlesnake (*Crotalus willardi*), and Mexican beaded lizard (*Heloderma horridum*).

Several species commonly thought of as desert dwellers actually occur in the tropical deciduous forest at their southernmost limits, but extend into arid desertlands in the southwestern United States. These species include the Sonoran desert toad (*Bufo alvarius*), regal horned lizard (*Phrynosoma solare*), zebra-tailed lizard (*Callisaurus draconoides*), western banded gecko, (*Coleonyx variegatus*), tiger rattlesnake (*Crotalus tigris*), saddled leaf-nosed snake (*Phyllorhynchus browni*), and desert tortoise (*Gopherus agassizi*).

Little is known about the status of amphibian populations in our region, especially in Mexico. Declines have been documented in populations of native ranid frogs in Arizona, with some leopard frog species severely affected by introduced predators such as bullfrogs and certain fishes (Clarkson & Rorabaugh 1989, Rosen et al. 1995). The Tarahumara frog (*Rana tarahumarae*) is extinct in the United States and has declined in some populations in northern Sonora, a decline that seems to be related to toxic fallout from copper smelters (Hale et al. in press). However, the greatest threat to the herpetofauna of the region is the clearing and conversion of tropical deciduous forest habitats for buffelgrass pasture.

INSECTS

In contrast to the eastern and southern states of Mexico, the northwestern Mexican states of Sonora, Chihuahua and Sinaloa are poorly known entomologically. It has been only recently that species lists have been produced for areas in the northern Sierra Madre Occidental. On the other hand, the insect faunas of Arizona and New Mexico are comparatively well known. As is most always the case with arthropod surveys, the first species lists generated deal with the more popular and manageable groups of insects, such as the Lepidoptera and Coleoptera.

While few insect families reach the northern limits of their range within the region, dozens of insect genera and hundreds or perhaps thousands of species reach the limits of their distributions here. Expansion and contraction of range is a relatively common phenomenon for a number of species in the region, consequently endemism seems to be rather low for most insect groups in the northern Sierra Madre Occidental. For example, there have been many well-known disappearances of insect species from the sky islands of southeastern Arizona (see Bailowitz & Brock 1991), e.g. Lepidoptera such as *Apodemia*

phyciodoides, Hylesia coinopus, Speyeria nokomis coerulescens, which in certain cases have been followed by apparent re-establishment of viable populations, e.g. *Gloveria howardi, Heliconius charitonius, Syssphinx raspa.* All these species are resident and abundant to the south. Still others are occasional interlopers from tropical areas, perhaps never able to survive in marginal habitats.

Many prominent tropical lepidopteran genera reach the northern limits of their ranges within our area: *Doxocopa, Heliconius, Hamadryas, Marpesia, Morpheis, Myscelia, Parides, Siproeta,* and many others. The large number of tropical plants found in the region insure that many associated insects are also present. For example, the tropical Brassolid genus, *Opsiphanes,* can be found as far north as the vicinity of Magdalena, Sonora, where the larvae feed upon palms (James Brock, pers. comm.). The Madrean region, specifically the more arid zones of the international border region, has the richest bee fauna in the world (Ayala et al. 1993). Certain epiphytic orchids are dependent upon Euglossine bees for pollination (Dressler 1993). Eluding discovery in the region until recently, *Euglossa* was found near Alamos, Sonora, in 1994 (Andrew Salywon, pers. comm.). The six species of Sonoran *Ficus* trees are accompanied by their obligate pollinators, minute wasps of the Agaonidae (Smith 1994). Trees of the Bombacaceae are at their northern limits in Sonora, as are the saturniid genera *Caio* and *Dysdaemonia* and the giant buprestid *Euchroma,* all of which are dependent upon these plants (Wolfe & Pescador 1994, Hespenheide 1983).

Fifty-two percent of the Sphingidae and approximately 79 percent of the Saturniidae confirmed for the state of Sonora are not found north of our region (Smith 1993, Peigler & Opler 1993). The northernmost populations of leaf-cutter ants (*Atta*) occur in southwestern Arizona (Byars 1949) and can be common in the more subtropical areas of the region, where their nests and middens are often host to passalid and scarabid beetles, various roaches and other commensal insects. The gregarious larvae of the pierid butterfly, *Eucheira socialis,* inhabit silk-pouches which are suspended from the foodplant, madrone (*Arbutus* spp.). The larvae and pupae have served as food for native peoples since prehistoric times (Castelló 1987). The silk of the larval pouches, which resembles chamois, has been used for a variety of utilitarian purposes in Mexico (Peigler 1993). Yaqui, Mayo and other tribes use the cocoons of *Rothschildia cincta* and a few other saturniid moths (Felger & Moser 1985, Peigler 1994) to make rattles which are used for ceremonial purposes. The large paper nests of honey wasps, *Brachygastra,* can be found on rock walls at least as far north as the vicinity of Nacori Chico, Sonora (Peter Jump, pers. comm.). The nests are harvested in Mexico as a wild source of honey.

With the striking examples of principally mesoamerican arthropods in the region, one might expect the presence of species of economic importance. Metallic-green *Haemagogus* mosquitoes, notorious yellow-fever vectors elsewhere (Hogue 1983), are present as are chiggers, fleas, ticks, Simuliid and Tabanid flies, Triatomine bugs, and other potential vectors of disease. While important vector-borne diseases, such as bubonic plague (Hoffmeister 1986) and malaria, are or have been present in Arizona, little work of medical or veterinary concern has been done in the neighboring Mexican portion of the region. Fruitflies of the genera *Anastrepha* and *Ceratitis* are able to establish themselves on the wide variety of both cultivated and wild fruits. These serious pests are a principal cause of restrictions placed upon international commerce in fruits.

ECONOMIC ASSESSMENT

Although only a few non-timber resources have been investigated for economic potential, cottage industries based on sustainable harvests of wild plants are possible. For example, it has been estimated that during a "dry" year roughly 20 tons of dry fruits of wild chiltepines (*Capsicum annuum* var. *aviculare*) are harvested in the state of Sonora, and that as much as 50 tons might be harvested during a "wet" year (De Witt 1991). The total export to the United States is about 6 tons, where the retail price in 1990 was $72 per pound (Nabhan 1990b).

An important medicinal plant of this region is chuchupate (*Ligusticum porteri, = L. madrensis*). The Tarahumara value the aromatic roots for medicinal and ritual purposes. Its popularity in the medicinal herb markets has increased to the point that over-collection has diminished or driven local populations to extinction. This moisture-and shade-loving species declines as forests are cleared and arroyo heads are eroded. Nevertheless, a local business is based upon the medicinal preparation called "COPANGEL," 2/5 of which is the ground root of this perennial herb. Based upon the retail value of this commercial product, one hectare of chuchupate is worth about $75,000. The roots are currently exported to the United

States, Japan, and Germany. Clinical studies by the Mexican national health program have determined that it is an effective treatment for peptic ulcers (Mundo et al. in press).

Emory Oak (*Quercus emoryi*) acorns, locally called *bellotas*, are wild-harvested each summer in northeastern Sonora and southeastern Arizona. A favorite of Sonorans and many Arizonans, the seeds are eaten fresh. They are sold locally, and in Sonoran markets and in Tucson they can be purchased for about $3.50 kg. Unlike many other kinds of acorns, they are palatable with no preparation due to a relatively low tannin content. These acorns have recently been shown to have an extremely high glycemic index value (Brand et al. 1990). Various other Madrean oaks likewise have "sweet" acorns and represent a potentially significant resource. The current price of acorn meal can be as high as $10 per pound in Korea, and the supply falls far short of the demand.

Several species of columnar cacti in the lowland, subtropical zones in Sonora and Chihuahua yield highly desirable fruits which can be eaten directly, dried or prepared as juice, condiments or wine. They are harvested for local consumption and occasionally reach marketplaces in nearby cities, such as Hermosillo, Sonora. The demand is high, and the vendors usually sell out very early on mornings when the fruit is available. Desirable species include the mountain organpipe or *saguira* (*Stenocereus montanus*) and the organpipe or *pitaya* (*Stenocereus thurberi*). Organpipe jam sells for $15/kg retail. Ten kg of fresh fruit yield one kg of jam. In some regions of northern Sonora, the local Indian people harvest 30 kg of fruit per person. Harvesting of columnar cactus fruit from wild populations by native peoples, at least in a subsistence economy, seems to have virtually no effect on the cactus populations (Felger & Moser 1985, Hastings & Turner 1965).

In recent years eco-tourism has provided a major economic resource for the region. This usually non-destructive industry is growing and expanding rapidly. The Tarahumara region in southwestern Chihuahua is especially popular, as is the Alamos area in southeastern Sonora. Bird-watching brings many people to the region, providing significant income for southeastern Arizona businesses.

THREATS

The remoteness of the rugged Sierras in Mexico with their relatively low human population densities and cultural conservatism have allowed the region to retain much of its ecosystem in a rather natural state. However, in the Sierra Madre Occidental, as in the rest of the world, an ever increasing human population is placing more demands on the environment. While many areas in Arizona and New Mexico are protected for the foreseeable future, certain Arizona mountains and many northern Mexico ranges are in a precarious situation.

Livestock exports to the United States are an important source of revenue for Mexican ranchers. Today, there are few places in northern Mexico free of cattle and goats. Overgrazing has reduced plant cover, hastened soil erosion and aggravated local flooding, with similar problems occurring in areas north of the international boundary. The wholesale clearing and replacement of native vegetation in Sonora and Sinaloa began about 30 years ago. Mexican ranchers continue to seed African buffelgrass (*Pennisetum ciliare*) over large tracts of cleared land. This practice constitutes the most serious cause of desertification in northern Mexico. While the land area devoted to buffelgrass pastures has not been adequately measured, estimates vary between 382,000 and 500,000 hectares for Sonora (Aguirre-Murrieta 1994). Comparable figures are probable for Sinaloa. The conversion to buffelgrass pastures has widespread support by Mexican state and federal governmental agencies and the practice is accelerating. In Sonora alone, government programs call for as much as 6 million additional hectares to be cleared and planted with this grass (Búrquez in press). Buffelgrass is well-suited to areas with little or no frost and a pronounced hot and dry season, therefore tropical deciduous forests are particularly at risk. If this conversion continues, only the most inaccessible tracts of this vegetation will remain in Mexico. Tropical deciduous forests are globally threatened.

Soil erosion has increased where native vegetation has been cleared and converted to farm lands. In subtropical regions there is a long history of slash and burn agriculture for milpas or rozas (cornfields) (Gentry 1942). Unlike large-scale commercial agriculture which is confined mostly to lowlands and valleys, damage caused by slash and burn practices is typical of rural areas and is often evident only in isolated regions. Many milpas occupy slopes of 45 degrees or more. Likewise, the selective cutting of hardwood legumes and other trees and shrubs for cooking fuel, home-heating and other purposes is not without environmental consequences. The cutting of *vara*

prieta (*Croton* cf. *niveus*) of southeastern Sonora for tomato stakes has made this once common tree scarce (Steinmann & Felger in press.).

Extensive over-harvesting of mesquite (*Prosopis velutina* and *P. glandulosa* var. *torreyana*) and desert ironwood (*Olneya tesota*), for charcoal exported primarily to the United States, threatens lowlands throughout the region (Nabhan & Carr 1994). Many of the subtropical hardwood trees such as amapa (*Tabebuia impetiginosa* and *T. chrysantha*) yield highly prized lumber for roof beams (*vigas*) and fine cabinet-making. The great sabinos or bald cypress (*Taxodium mucronatum*) yield a durable wood which commands a high price. These and many other species are legally protected by the Mexican forestry department but, as in many other remote regions of the world, enforcement is often difficult.

The ever-present demand and shortage of fresh water in nearby desert communities puts a serious strain on the water resources of the region. Every river system in the region has been dammed, and all river deltas have been seriously damaged. The construction of a large dam near Huites, Sinaloa, will create a large reservoir on the middle Río Fuerte, backing up water into the lower reaches of the Barranca del Cobre. Thousands of hectares of riparian habitat will be flooded and much of the remaining tropical deciduous forest and coastal thornscrub are being cleared downstream for concomitant irrigation districts. Other major canyons will certainly be considered as sites for reservoirs.

Northern Mexico's mining history is famous. Spaniards began operation of mines as long ago as 1620. Open pit copper mines at Cananea and Nacozari have been expanded, while others in Sonora are being developed, such as northeast of Cucurpe, the vicinity of Mulatos, and at Piedras Verdes near Alamos. These activities pose a continuing threat to the environment. Air pollution from smelters, such as at Cananea and Nacozari in northeastern Sonora have serious effects on certain animals (Hale et al. in press).

Cultivation of marijuana and opium poppies, usually considered a legal problem, poses a major ecological, social and economic threat. The presence of an armed group of drug cultivators, buyers and distributors is a danger to the local inhabitants, tourists and scientists. Native peoples in the Sierra Madre Occidental have been forced to cultivate and harvest drug crops by criminals from outside the mountain communities. Failure to cooperate with druglords and their underlings has resulted in injury and death (Weisman 1994). Aerial spraying of herbicides by law enforcement agencies to eliminate drug plantations has caused extensive but undocumented and unstudied damage to the native vegetation and flora, and may be a human health hazard. The application of herbicides on Sierra Alamos and elsewhere threatens unique populations of tropical species.

The most dire threats to the sierras are the logging and pulping industries. The heartland of the Sierra Tarahumara presently contains only two percent old growth stands of conifers (Burns et al. 1994). Almost all of the coniferous forests of northern Mexico have been cut one to four times during the twentieth century. Large-scale financing is supporting clear-cutting, harvesting and destruction of understory trees and plants, and pulping of diverse species. A major forestry development project for Chihuahua and Durango proposed by the World Bank (Seedhead News 1991) has been scrapped, but similar projects are likely to be instigated. A large pulp mill at Anahuac, Chihuahua, has been expanded and renovated with a US $350 million loan from the Chase Manhattan Bank. The 1993 North American Free Trade Agreement (NAFTA) will undoubtedly encourage increased exploitation of Mexican raw materials. It will be an international challenge to avert the inevitable environmental problems including loss of biological diversity.

Recently, there have been changes in governmental policy which may counter the increasing awareness of environmental concerns in Mexico. In 1992, Article 27 of the Constitution of Mexico was modified in order that ejidos (communal land-holding organizations) have the option to disincorporate. Ejidos have controlled 70 percent of the land in the northern Sierra Madre since the 1930s. Disincorporation can lead to privatization and sale of forested lands to large corporations. Similarly, Indian ancestral land claims appear to be weakened by recent constitutional changes.

Revision of Mexico's forestry laws have been made that allow "long term leases of forested land to foreign companies. It also would eliminate requirements for environmental impact studies, allow transnational corporations to replace native vegetation with commercial agroforestry plantations of exotic species, and eliminate extraction authorization requirements that provide monitoring of forestry projects and environmental conditions. All of the major NGO and environmental organizations in Mexico have opposed these revisions, maintaining they invade the rights of indigenous peoples and diminish eco-

nomic benefits to ejidos, indigenous communities, and small forest proprietors." (Burns et al. 1994)

CONSERVATION

Most of the sky island mountains of southeastern Arizona and New Mexico are administered by the United States National Forest Service, which is faced with the conflicting responsibilities of conservation, generating revenue from timber sales, providing leases for grazing and development, and furnishing recreational areas. Interest in development of mountain areas for housing and resorts is of recurrent concern for environmentalists and scientists. The construction of telescopes on Mt. Graham, in the Pinaleño Mountains, has been a source of tremendous dissension among conservationists, U.S. federal agencies and the University of Arizona. A substantial portion of the Huachuca Mountains is protected by incorporation into the Ft. Huachuca Military Reservation. The Gray Ranch in southwestern New Mexico, which includes the Animas Mountains, was purchased by The Nature Conservancy in 1990 and protection continues under the Animas Foundation to which this property has been transferred. The Atascosa, Baboquivari, Chiricahua, Dragoon, Huachuca, Peloncillo, Rincon, Santa Rita, Santa Catalina, and other smaller mountain ranges are protected as Coronado National Forest, U.S. National Monuments, state parks, or a combination of these or other protected designations.

Conservation efforts in Mexico have suffered from underfunding and neglect. Although several areas in northwestern Mexico have special conservation status, enforcement of environmental policy and protection of natural areas has been lax or nonexistent. For instance, in Sonora the Sierra Bavispe, Sierra de los Ajos and the nearby Sierra de la Purica and Sierra Buenos Aires were granted protection during the 1930s. However these areas have not been managed as preserves and, like many other areas that have been given special status, they have not escaped logging or cattle ranching (Búrquez in press).

Mexico, however, maintains a bulwark of governmental agencies that could be very effective in the conservation of natural areas. Many of the mountainous areas in Mexico are under the control of the Mexican federal government, either that of the Secretary of Agriculture (SARH) which manages forest refuges and national parks, or the Subsecretary of Ecology, of the Secretary of Social Development (SEDESOL), which manages the national system of protected areas. Mexico does not lack in its pool of talented and educated individuals who could effect change in environmental policy. Various institutions have been active in attempting to gain or increase protection for new and existing nature preserves.

Preservation of important natural areas can be complemented by land management programs involving local communities. In diverse parts of the region, *in situ* conservation by indigenous and other rural people has been informal but often effective. Some of these activities are becoming formalized. The Arizona Rainforest Alliance, Forest Guardians, the Advisory Council of the Sierra Madre, and the Regional Confederation of the Tepehuan and Tarahumara People are working with a number of Tarahumara and Northern Tepehuan communities to set up a series of community-managed bioreserves in the Sierra Madre Occidental. Many of the indigenous ejidos want to protect their ancestral forests but lack the official mechanism to achieve such measures. Gaining official protection for these areas needs support from all concerned organizations.

The northern Sierra Madre has a few small areas that have been granted special protection such as the Cascada de Basaseachic National Park. There are several designated National Forest Reserves in the four-state area of the northern Sierras, including those at Campo Verde, Papigochic, and Tutuaca, in Chihuahua; the Sierras de los Ajos, Buenos Aires, La Purica and others, in Sonora; and El Centenaria, in Durango. There are also more than a dozen nominally protected forest zones in these states, but these remain areas for multiple use or for recovery after severe overharvesting.

Important areas which have been proposed to receive protection are the Barranca del Cobre with the Barranca Sinforosa, and Sierra Mohinora, Chihuahua; the Sierra Mazatán, Sierra la Mariquita, Mesa El Campañero, Arroyo el Reparo near Yécora, the Sierra Alamos with the upper Río Cuchujaqui region southeast of Alamos, and other areas in Sonora; and the Sierra San Luis on the Sonora-Chihuahua border (Búrquez in press, Felger et al. in press). In addition to the Biosphere reserve at La Michilia, Durango, there are other areas that are worthy of this designation. Notable areas under consideration by local governments for conservation include: Cañón la Cruz del Diablo east of Guasabas, Sonora; the Sierra el Tigre near Huachinera, Sonora; Cañón de Tepoca, Sonora; Laguna de Babichic, Chihuahua; the Llanos

de Carretas, Chihuahua; the Sierra Mohinora, Durango; and the Barrancas of the Río Verde.

CONCLUSION

The rugged Madrean region of northern Mexico is complex. Its forests are the largest terrestrial oxygen-biomass producing ecosystems remaining in southwestern North America. The nature of the region is largely one of endpoints, meeting places and overlap—a peculiar combination of xeric, temperate and tropical elements determined by unique combinations of geography, topography, and climate. Remarkable assemblages of biotic communities are frequent here and many organisms are at the very limits of their ranges. Such places are not common on our planet. Our hope is to encourage interest in an area that has often been overlooked by researchers.

Scientific interest in the region will have important ramifications for conservation, for it will be through documentation and publicizing

that protection will be forthcoming. The future of many areas is tenuous. Development is exacting an enormous toll and this is particularly true of the southern portion of the region. We hope that all involved parties—government, business, conservation organizations and the local populace—will have the opportunity and wisdom to act with careful deliberation in their future endeavors.

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Appendix 1. Some Apachian-Madrean endemic or near-endemic plants.

ACANTHACEAE - ACANTHUS FAMILY
Stenandrium pilosulum (Blake) T.F. Daniel
Tetramerium abditum (Brandegee) T.F. Daniel

AGAVACEAE - CENTURY PLANT FAMILY
Agave bovicornuta Gentry
A. jaiboli Gentry
A. palmeri Engelm.
A. parryi Engelm. var. *huachucensis* (Baker) Little
A. parviflora Torr. subsp. *flexiflora* Gentry
A. parviflora subsp. *parviflora*
A. polianthiflora Gentry
A. shrevei Gentry subsp. *magna* Gentry
A. shrevei subsp. *shrevei*
Hesperaloe nocturna Gentry
H. tenuifolia G. Starr ined.
Yucca grandiflora Gentry
Y. madrensis Gentry
Y. schottii Engelm.

ALLIACEAE - ONION FAMILY
Allium plummerae S. Watson

AMARYLLIDACEAE - AMARYLLIS FAMILY
Hymenocallis pimana Laferrière

APIACEAE (UMBELLIFERAE) - CARROT FAMILY
Arracacia edulis S. Watson
Eryngium lemmoni Coult. & Rose
Prionosciadium madrense S. Watson
P. townsendi Rose
Tauschia alloides Bye & Const.
T. bicolor Const. & Bye
T. tarahumara Const. & Bye

APOCYNACEAE - DOGBANE FAMILY
Amsonia grandiflora Alexander
A. kearneyana Woods.
Macrosiphonia brachysiphon (Torr.) A. Gray
M. woodsoniana Standl.

AQUIFOLIACEAE - HOLLY FAMILY
Ilex rubra S. Watson

ASCLEPIADACEAE - MILKWEED FAMILY
Asclepias mirifica Woods.
Cynanchum wigginsii Shinners
Gonolobus gonoloboides (Greenm.) Woods.
Metastelma latifolium Rose

ASPLENIACEAE - SPLEENWORT FAMILY
Woodsia cochisensis Windham

ASTERACEAE (COMPOSITAE) - ASTER FAMILY
Acourtia dieriergeri Cabrera
Alomia stenolepis Blake
Ageratina palmeri (A. Gray) Gage
A. paupercula (A. Gray) R.M. King & H. Robins.
A. sandersii B.L. Turner
A. stricta (A. Gray) R.M. King & H. Robins.
A. yecorana B.L. Turner
A. venulosum (A. Gray) King & Robins.
Berlandiera lyrata A. Gray var. *monocephala* B.L. Turner
Bidens gentryi Sherff
Brickellia betonicifolia A. Gray
B. floribunda A. Gray
B. lemmoni A. Gray
B. lewisii B.L. Turner
B. simplex A. Gray
Carphochaete pringlei (S. Watson) B.L. Turner
Circium basaseachense Nesom
C. rothrockii (A. Gray) Petrak
Cosmos palmeri B.L. Robins.
Erigeron basaseachensis Nesom
E. byei Sundberg & Nesom
E. circulis Nesom
E. dactyloides (Greenm.) Nesom
E. eruptens Nesom
E. fundus Nesom
E. jenkinsii Nesom
E. heliographis Nesom
E. kuschei Eastw.
E. lemmonii A. Gray
E. macdonaldii Nesom
E. mayoensis Nesom
E. mohinorensis Nesom
E. naroiensis Nesom
E. podophyllus Nesom
E. rhizomactus Nesom
E. sceptrifer Nesom
E. strigulosus Greene
Heterotheca rutteri (Rothr.) Shinners
Hieraceum carneum Greene
H. lemmoni A. Gray
Hymenothrix palmeri A. Gray var. *glandulosa* (S. Watson) B.L. Turner
Hymenoxys quinquesquamata Rydb.
Iostephane madrensis (S. Watson) Strother
Laennecia chihuahuana Nesom
L. eriophylla (A. Gray) Nesom
L. pimana Nesom & Laferrière
Lasianthaea podocephala (A. Gray) K. Beeker
Leibnitzia occimadrensis Nesom
Melampodium longicorne A. Gray
Pectis imberbis A. Gray
P. pimana Laferrière & Keil
Perityle batopilensis A.M. Powell
P. cochisensis (Niles) A.M. Powell
P. gentryi A.M. Powell
P. microcephala A. Gray
Pinaropappus junceus A. Gray
P. pooleana B.L. Turner
Plummera ambigens Blake
P. floribunda A. Gray
Senecio mayoensis B.L. Turner
S. tepopana B.L. Turner
Stevia martinii B.L. Turner
Tagetes lemmoni A. Gray
T. palmeri A. Gray
Tomentaurum niveum (S. Watson) Nesom
Tridex erecta A. Gray
Verbesina callilepis Blake
V. gentryi Standl.
V. joyaliae B.L. Turner
Viguiera montana A. Gray
V. ovalis Blake
V. triloba (A. Gray) Olsen
Wedelia chihuahuana B.L. Turner
W. gentryi B.L. Turner
W. pimana B.L. Turner

Xanthocephalum gymnospermoides (A. Gray) Benth. & Hook. var. *eradiatum* M.E. Lane

BERBERIDACEAE - BARBERRY FAMILY
Berberis longipes La Ferr.
B. pimana Laferrière & Marr.

BORAGINACEAE - BORAGE FAMILY
Lithospermum obovatum MacBride

BRASSICACEAE (CRUCIFERAE) - MUSTARD FAMILY
Arabis microsperma Rollins
A. tricornuta Rollins
Draba petrophila Greene var. *petrophila*
D. petrophila var. *viridis* (A.A. Heller) C.L. Hitchc.
D. rubicaulis A.A. Heller
Romanschulzia correllii Rollins
Thelypodiopsis byei Rollins
T. wootonii (Robins.) Rollins var. *parviflora* Rollins
T. wootonii var. *wootonii*

BROMELIACEAE - PINEAPPLE FAMILY
Tillandsia cretacea L.B. Smith
T. elizabethae Rauh

CACTACEAE - CACTUS FAMILY
Coryphantha recurvata (Engelm.) Britt. & Rose
C. robbinsorum (W.H. Earle) A.D. Zimmerm.
Echinocereus adustus Engelm. var. *adustus*
E. bristolii W.T. Marsh.
E. lauii G.R.W. Frank
E. ledingii Peebles
E. rigidissimus (Engelm.) Hort. F. A. Hodge var. *rigidissimus*
E. rigidissimus var. *rubispinosus* (G.R.W. Frank & Lau) N.P. Taylor
E. scheeri (Salm-Dyck) Scheer var. *gentryi* (Clover) N.P.Taylor
E. scheeri var. *obscuriensis* A. Lau
E. stoloniferus W.T. Marsh. var. *stoloniferus*
E. stoloniferus var. *tayopensis* (W.T. Marsh.) N.P. Taylor
Ferocactus alamosanus Britt. & Rose
F. pottsii (Salm-Dyck) Backeb.
Mammillaria barbata Engelm.
M. bocensis Craig var. *movasana* Reppenhagen
M. lindsayi Craig
M. macdougalii Rose
M. meigiana H. Earle
M. saboae Glass var. *goldii* (Glass & Foster) Glass & Foster
M. saboae var. *haudeana* (A. Lau & Wagner) Glass & Foster
M. saboae var. *saboae*
M. sonorensis Craig
M. standleyi (Britt. & Rose) Orcutt var. *standleyi*
M. wrightii Engelm. var. *wilcoxii* W.T. Marsh.
Opuntia santa-rita Griffiths & Hare

CAMPANULACEAE - CAMPANULA FAMILY
Lobelia cordifolia Hook. & Arn.
L. endlichii (F. Wimmer) Ayers
L. knoblochii Ayers

CAPRIFOLIACEAE - HONEYSUCKLE FAMILY
Lonicera cerviculata S.S. White

CARYOPHYLLACEAE - PINK FAMILY
Silene thurberi S. Watson

CHENOPODIACEAE - GOOSEFOOT FAMILY
Atriplex griffithsii Standl.

CISTACEAE - ROCK ROSE FAMILY
Helianthemum chihuahuense S. Watson

CONVOLVULACEAE - MORNING GLORY FAMILY
Ipomoea arborescens (Humb. & Bonpl.) G. Don var. *pachylutea* Gentry
I. thurberi A. Gray
I. chilopsidis Standl
I. tenuiloba Torr. var. *lemmonii* (A. Gray) Yatsk. & C. Mason

CRASSULACEAE - STONECROP FAMILY
Echeveria chihuahuensis von Pollnitz
E. craigiana E. Walther
Graptopetalum bartramii Rose
G. occidentalis Rose & Walther
Sedum lumholtzii Robins. & Fernald
S. madrense S. Watson
S. mellitulum Rose
Tacitus bellus Moran & Meyran

EBENACEAE - PERSIMMON FAMILY
Diospyros sonorae Standl.

EUPHORBIACEAE - SPURGE FAMILY
Croton sp. "Yécora"
Tragia laciniata (Torr.) Müll. Arg.

FABACEAE (LEGUMINOSAE)- LEGUME FAMILY
Acacia millefolia S. Watson
Astragalus gentryi Standl.
A. hypoxylus S. Watson
A. thurberi A. Gray
Coursetia barrancana Lavin
C. glabella (A. Gray) Lavin
Dalea lumholtzii B.L. Robins. & Fernald
D. pinetorum Gentry var. *anilantha* Barneby
D. pinetorum var. *pinetorum*
D. pringlei A. Gray var. *oxyphyllidia* Barneby
D. pringlei var. *pringlei*
D. tentaculoides Gentry
D. tomentosa (Cav.) Willd. var. *mota* Barneby
Lotus alamosanus (Rose) Gentry
Lupinus huachucanus M.E. Jones
L. lemmoni C.P. Smith
Marina alamosana (Rose) Barneby
M. goldmanii (Rose) Barneby
Mimosa grahami A. Gray var. *prolifica* (S. Watson) Barneby
Mimosa guiracobensis Gentry
M. pauli Barneby
Nissolia gentryi Rudd
Phaseolus parvulus Greene
P. salicifolius Piper
P. supinus Wiggins & Rollins
Zapoteca formosa (Kunth) H. Hern. subsp. *formosa*

FAGACEAE - BEECH FAMILY
Quercus tarahumara Spellenb., Bacon & Breedl.
Q. toumeyi Sarg.

GENTIANACEAE - GENTIAN FAMILY
Centaurium gentryi Broome
Gentianella microcalyx (Lemmon) J.M. Gillett

HYDROPHYLLACEAE - WATERLEAF FAMILY
Phacelia arizonica A. Gray

LAMIACEAE (LABIATAE) - MINT FAMILY
Agastache breviflora (A. Gray) Epling
A. mearnsii Woot. & Standl.
A. pallida (Lindley) Kory var. *coriacea* A. Sanders
Hedeoma dentatum Torr.
H. floribundum Standl.
H. oblongifolium (A. Gray) A.A. Heller var. *mexicanum* Irving
Hyptis seemannii A. Gray
Salvia alamosana Rose
S. goldmanii Fernald
S. lemmonii A. Gray

MALVACEAE - MALLOW FAMILY
Anoda succulenta Fryxell
Kosteletzkya thurberi A. Gray
Sida hyalina Fryxell

NOLINACEAE - BEARGRASS FAMILY
Nolina matapensis Wiggins

OLEACEAE - OLIVE FAMILY
Fraxinus gooddingii Little

PASSIFLORACEAE - PASSIFLORA FAMILY
Passiflora quercetorum Killip

POACEAE (GRAMINEAE) - GRASS FAMILY
Bouteloua alamosana Vasey
B. eludens Griffiths
Muhlenbergia capillipes (M.E. Jones) Peterson & Annable
M. dubioides C.O. Goodding
M. xerophila C.O. Goodding
Setaria arizonica Rominger

POLEMONIACEAE - PHLOX FAMILY
Ipomopsis macombii (Torr.) V. Grant
I. thurberi (Torr.) V. Grant
Polemonium glabrum J.F. Davidson
Polemonium sp. (Basaseachic)

POLYGALACEAE - MILKWORT FAMILY
Polygala orthotrica Blake
P. piliophora Blake

PRIMULACEAE - PRIMROSE FAMILY
Primula rusbyi Greene

RANUNCULACEAE - BUTTERCUP FAMILY
Delphinium andesicola Ewan

ROSACEAE - ROSE FAMILY
Potentilla albiflora L.O. Williams
Prunus gentryi Standl.
P. zinggii Standl.

RUBIACEAE - MADDER FAMILY
Crusea wrightii A. Gray var. *wrightii*
Hedyotis spellenbergii Nesom & Vorobik

SCROPHULARIACEAE - SNAPDRAGON FAMILY
Brachystigma wrightii (A. Gray) Pennell
Limosella pubiflora Pennell
Mabrya geniculata (Robins. & Fernald) Elisens subsp. *geniculata*
M. geniculata subsp. *lanata* Elisens
Mimulus pallens Greene
Penstemon fasciculatus A. Gray
P. discolor Keck

SOLANACEAE - NIGHTSHADE FAMILY
Browallia eludens R. VanDevender & P. Jenkins

TILIACEAE - LINDEN FAMILY
Triumfetta chihuahuensis Standl.

VALERIANACEAE - VALERIAN FAMILY
Valeriana apiifolia A. Gray

VERBENACEAE - VERBENA FAMILY
Lippia gentryi Standl.

Appendix 2. Selected, southern (tropical) plant families and genera at their northern limits in western North America.

FAMILIES (genera)

Begoniaceae (*Begonia*)
Bombacaceae (*Ceiba*, *Pseudobombax*)
Bromeliaceae (*Pitcairnia*, *Tillandsia*)
Caricaceae (*Jarilla*)
Clethraceae (*Clethra*)
Cochlospermaceae (*Amoreuxia*, *Cochlospermum*)
Eriocaulaceae (*Eriocaulon*)
Erythroxylaceae (*Erythroxylum*)
Gesneriaceae (*Achimenes*)
Magnoliaceae (*Magnolia*)
Meliaceae (*Cedrella*, *Trichilia*)
Melastomataceae (*Clidemia*)
Myrsinaceae (*Ardisia*, *Myrsine*)
Myrtaceae (*Psidium*)
Olacaceae (*Schoepfia*)
Opiliaceae (*Agonandra*)
Piperaceae (*Piper*)
Zamiaceae (*Dioon*)

GENERA

ACANTHACEAE - ACANTHUS FAMILY
Blechum
Elytraria
Henrya
Pseuderanthemum
Tetramerium

APOCYNACEAE - DOGBANE FAMILY
Mandevilla
Plumeria
Stemmadenia

AMARYLLIDACEAE - AMARYLLIS FAMILY
Sprekelia

ARALIACEAE - GINSENG FAMILY
Oreopanax

ARECACEAE (PALMAE) - PALM FAMILY
Brahea
Sabal

ASCLEPIADACEAE - MILKWEED FAMILY
Pherotrichis

ASTERACEAE (COMPOSITAE) - ASTER FAMILY
Ageratum
Alloispermum
Blumea
Calea

Dahlia
Elephantopus
Jaegeria
Lagascea
Lasianthaea
Milleria
Montanoa
Perymerium
Sclerocarpus
Tithonia
Tridax
Trigonospermum
Wedelia

BIGNONIACEAE - BIGNONIA FAMILY
Tabebuia

BORAGINACEAE - BORAGE FAMILY
Cordia

CACTACEAE - CACTUS FAMILY
Pilosocereus

CELASTRACEAE - STAFF-TREE FAMILY
Schafferia
Wimmeria

CISTACEAE - ROCK ROSE FAMILY
Lechea

COMMELINACEAE - SPIDERWORT FAMILY
Gibasis
Tripogondra

CRASSULACEAE - STONECROP FAMILY
Echeveria

CUCURBITACEAE - GOURD FAMILY
Cremastopus
Cyclanthera
Sechiopsis

EUPHORBIACEAE - SPURGE FAMILY
Dalechampia
Drypetes
Sebastiana

FABACEAE (LEGUMINOSAE) - LEGUME FAMILY
Albizia
Bauhinia
Brongniartia
Conzattia
Leucaena
Lonchocarpus
Lysiloma
Piscidia
Platymiscium

HYDRANGEACEAE - HYDRANGEA FAMILY
Hydrangea

IRIDACEAE - IRIS FAMIY
Tigridia

LAURACEAE - LAUREL FAMILY
Cinnamomum
Persea

LYTHRACEAE - LOOSESTRIFE FAMILY
Cuphea

MALPIGHIACEAE - MALPIGHIA FAMILY
Aspicarpa
Bunchosia
Callaeum

MORACEAE - MULBERRY FAMILY
Chlorophora
Dorstenia
Ficus
Trophis

ONAGRACEAE - EVENING PRIMROSE FAMILY
Gongylocarpus
Lopezia

OPILIACEAE - OPILIA FAMILY
Agonandra

ORCHIDACEAE - ORCHID FAMILY
Bletia
Brassovola
Cattleya
Cuitlauzinia
Cyrtopodium
Encyclia
Govenia
Laelia
Oncidium
Stanhopea

PAPAVERACEAE - POPPY FAMILY
Bocconia

POACEAE (GRAMINEAE) - GRASS FAMILY
Chaetium
Lasiacis
Pennisetum
Pereilema
Otatea

RUBIACEAE - RUE FAMILY
Chiococa
Hintonia
Hamelia
Psychotria
Randia

SAPINDACEAE - SOAPBERRY FAMILY
Paulinia
Serjania
Thouinia

SCROPHULARIACEAE - SNAPDRAGON FAMILY
Buchnera
Escobedia
Lamourouxia
Russelia
Seymeria

SIMAROUBACEAE - SIMAROUBA FAMILY
Alvaradoa

SOLANACEAE - NIGHTSHADE FAMILY
Cestrum
Jaltomata

STERCULIACEAE - STERCULIA FAMILY
Guazuma
Melochia

TILIACEAE - LINDEN FAMILY
Corchorus
Heliocarpus
Triumfetta

ULMACEAE - ELM FAMILY
Aphananthe

URTICACEAE - NETTLE FAMILY
Pouzolzia
Urea

VERBENACEAE - VERBENA FAMILY
Priva
Vitex

VIOLACEAE - VIOLET FAMILY
Hybanthus

Appendix 3. Genetic resources for crop improvement: wild relatives of domesticated, or economically valuable plants.

ACERACEAE - MAPLE FAMILY
Acer glabrum Pursh
A. grandidentatum Nutt.
A. negundo L.

AGAVACEAE - CENTRY PLANT FAMILY
Agave angustifolia Haw. var. *angustifolia*
A. bovicornuta Gentry
A. jaiboli Gentry
A. multifilifera Gentry
A. ocahui Gentry
A. palmeri Engelm.
A. parryi Engelm.
A. parviflora Torr.
A. polianthiflora Gentry
A. schottii Engelm.
A. shrevei Gentry
A. vilmoriniana Berger
A. wocomahi Gentry
Yucca arizonica McKelvey
Y. grandiflora Gentry
Y. madrensis Gentry
Y. schottii Engelm.

ALLIACEAE - ONION FAMILY
Allium cernuum Roth.
A. glandulosum Link & Otto.
A. gooddingii Ownbey
A. kunthii G. Don
A. plummerae S. Watson

AMARANTHACEAE - AMARANTHUS FAMILY
Amaranthus fimbriatus (Torr.) Benth.
A. hybridus L.
A. palmeri S. Watson

ASTERACEAE (COMPOSITAE) - ASTER FAMILY
Helianthus annuus L.
Porophyllum coloratum (H.B.K.) DC.
P. macrocephalum DC.

BRASSICACEAE (CRUCIFERAE) - MUSTARD FAMILY
Lepidium densiflorum Schrader
L. lasiocarpum Nutt.
L. medium Greene
L. thurberi Woot.
L. virginicum L.

CACTACEAE - CACTUS FAMILY
Opuntia engelmannii Engelm.
O. durangensis Britt. & Rose
O. karwinskiana Salm-Dyck
O. robusta Pfeiff.
O. wilcoxii Britt. & Rose

CHENOPODIACEAE - GOOSEFOOT FAMILY
Chenopodium album L.
C. ambrosioides L.
C. incisum Poir.
C. neomexicanum Standl.
C. pratericola Rydb.

CONVOLVULACEAE - MORNING GLORY FAMILY
Ipomoea alba L.
I. ancisa House
I. arborescens (Humb. & Bonpl.) G. Don
I. aristolochiaefolia (H.B.K.) G. Don
I. barbatisepala A. Gray
I. bracteata Cav.
I. cairica (L.) Sweet
I. capillacea (H.B.K.) G. Don
I. cardiophylla A. Gray
I. chilopsidis Standl.
I. costellata Torr.
I. cristulata Hallier
I. fistulosa (Mart.) D. Austin
I. hederacea Jacq.
I. imperati (Vahl.) Griseb.
I. jalapa (L.) Pursh
I. lactescens Benth.
I. laeta A. Gray
I. xleucantha Jacq.
I. leptotoma Torr.
I. meyeri G. Don
I. minutiflora (Mart. & Gal.) House
I. muricata (L.) Jacq.
I. nil (L.) Roth.
I. pedatisecta Mart. & Gal.
I. pedicellaris Benth.
I. plummerae A. Gray
I. pubescens Lam.
I. pulchella Roth.
I. purpurea (L.) Lam.
I. quamoclit L.
I. scopulorum Brandegee
I. tenuiloba Torr. var. *lemmonii* (A. Gray) Yatsk. & Mason
I. tenuiloba var. *tenuiloba*
I. turbinata Lag.
I. thurberi A. Gray
I. triloba L.
I. wrightii A. Gray

CUCURBITACEAE - GOURD FAMILY
Cucurbita argyrosperma Huber subsp. *argyrosperma* var. *palmeri* (L.H. Bailey) Merrick & Bates
C. foetidissima H.B.K.
Luffa operculata (L.) Cogn.

DIOSCOREACEAE - YAM FAMILY
Dioscorea remotiflora Kunth
Dioscorea sp.

EBENACEAE - PERSIMMON FAMILY
Diospyros sonorae Standl.

ERICACEAE - HEATHER FAMILY
Vaccinium caespitosum Michx.
V. confertum H.B.K.
V. oreophyllum Rydb.

ERYTHROXYLACEAE - COCA FAMILY
Erythroxylum mexicanum H.B.K.

EUPHORBIACEAE - SPURGE FAMILY
Manihot aesculifolia (H.B.K.) Pohl.
M. angustiloba (Torr.) Müll.Arg.
M. davisiae Croiz.
M. rubicaulis I.M. Johnst.
Manihot sp. (tree)

FABACEAE (LEGUMINOSAE) - LEGUME FAMILY
Canavalia villosa Benth.
Indigofera densiflora Mart. & Gal.
I. macilenta Standl.
I. suffruticosa Mill.
Leucaena lanceolata S. Watson
Phaseolus acutifolius A. Gray var. *acutifolius*
P. acutifolius var. *tenuifolius* A. Gray
P. coccineus L. subsp. *formosus* (Kunth) M.M.& S.
P. coccineus subsp. *glabellus* (Piper) Delgado
P. leptostachyus Benth.
P. falciformis Piper
P. leptostachyus Benth. var. *leptostachyus*
P. leptostachyus var. *micranthus* (Hook. & Arn.) Delgado
P. lunatus L. var. *silvester* Baudet
P. maculatus Scheele subsp. *maculatus* Freytag
P. maculatus subsp. *ritensis* (M.E. Jones) Freytag
P. microcarpus Mart.
P. parvulus Greene
P. pauper Standl.
P. pauciflorus Ses. & Moç.
P. pedicellatus Benth. var. *grayanus* (Woot. & Standl.) A. Delgado
P. pedicellatus var. *polymorphus* (S. Watson) Delgado
P. pluriflorus Mareschal et al.
P. salicifolius Piper
P. sempervirens Piper
P. xantotrichus Piper

GROSSULARIACEAE - GOOSEBERRY FAMILY
Ribes cf. *brandegeii* Eastw.
R. ceriferum Cov. & Rose
R. pinetorum Greene

JUGLANDACEAE - WALNUT FAMILY
Juglans major (Torr.) Heller

LAMIACEAE (LABIATAE) - MINT FAMILY
Hyptis emoryi Torr.
H. mutabilis (Rich.) Briq.
H. seemannii A. Gray
H. septentrionale Epling
H. stellulata Benth.
H. suaveolans (L.) Poit.
Salvia alamosana Rose
S. azurea Lam.
S. betuliifolia Epling
S. cinnabarina Mart. & Gal.
S. elegans Vahl var. *sonorensis* Fernald
S. fluviatilis Fernald
S. goldmanii Fernald
S. greggii A. Gray
S. hispanica L.
S. lasiosepala Hook. & Arn.
S. lemmoni A. Gray
S. melissodora Lag.
S. mexicana L.
S. monantha Brandegee
S. muscaroides Fernald
S. palmeri A. Gray
S. reptans Jacq. var. *glabra* (A. Gray) K.M. Peterson
S. riparia Kunth
S. roscida Fernald
S. seemannii Fernald
S. setosa Fernald
S. tiliaefolia Vahl

LAURACEAE - LAUREL FAMILY
Cinnamomum sp.
Persea podadenia Blake

MALPIGHIACEAE - MALPIGHIA FAMILY
Malpighia emarginata DC.

MALVACEAE - Mallow Family
Gossypium thurberi Todaro

MELIACEAE - CHINA-BERRY FAMILY
Cedrela odorata L.

MORACEAE - MULBERRY FAMILY
Ficus cotinifolia H.B.K.
F. insipida Willd.
F. maxima Mill.
F. pertusa L. f.
F. petiolaris H.B.K.
F. trigonata L.
Morus microphylla Buckl.

MYRTACEAE - MYRTLE FAMILY
Psidium sartorianum (Berg.) Ndzu.

PINACEAE - PINE FAMILY
Abies bifolia A. Murr.
A. concolor (Gordon & Glend.) Hildebr.
A. durangensis Martínez
Pinus cembroides Zucc.
P. douglasiana Martínez
P. durangensis Martínez
P. edulis Engelm.
P. englemannii Carr.
P. herrerae Martínez
P. leiophylla Scheide & Deppe var. *chihuahuana* (Engelm.) Shaw
P. lumholtzii Robins. & Fernald
P. maximinoi H.E. Moore
P. oocarpa Scheide
P. ponderosa Laws. & C. Laws. var. *arizonica* (Engelm.) Shaw
P. ponderosa var. *scopulorum* Engelm.
P. strobiformis Engelm.
Pseudotsuga menziesii (Mirb.) Franco var. *glauca* (Mayr) Franco

PIPERACEAE - PEPPER FAMILY
Piper hispidum Sw.
P. jaliscanum S. Watson

PLANTAGINACEAE - PLANTAIN FAMILY
Plantago alismatifolia Pilger
P. australis Lam. var. *hirtella* (H.B.K.) Rahn
P. argyrea Morris
P. cf. *lanceolata* L.
P. linearis H.B.K.
P. patagonica Jacq.

POACEAE (GRAMINEAE) - GRASS FAMILY
Eragrostis ciliaris (L.) R. Br.
E. erosa Scribn.
E. intermedia Hitchc.
E. maypurensis (H.B.K.) Steud.
E. mexicana (Hornem.) Link subsp. *mexicana*
E. pectinacea (Michx.) Nees var. *miserrima* (Fourn.) J. Reeder
E. pectinacea var. *pectinacea*
Hordeum pusillum Nutt.
Pennisetum karwinskii Schrader
Setaria arizonica Rominger
S. grisebachii Fourn.
S. leucopila (Scrib. & Merr.) K. Schum.
S. liebmannii Fourn.
S. longipila Fourn.
S. pumila (Poiret) Roemer & Schultes
Zea mays L. subsp. *mexicana* (Schrad.) Iltis

RHAMNACEAE - BUCKTHORN FAMILY
Ziziphus amole (Ses. & Moç.) M.C. Johnst.
Z. obtusifolius (Torr. & A. Gray) A. Gray var. *canescens* (A. Gray) M.C. Johnst.

ROSACEAE - ROSE FAMILY
Fragaria ovalis (Lehm.) Rydb.
F. vesca L. subsp. *bracteata* (Heller) Staudt.
Prunus serotina Ehrh. subsp. *capuli* (Cav.) McVaugh
P. serotina subsp. *virens* (Woot. & Standl.) McVaugh
P. emarginata (Dougl.) D. Dietr.
P. gentryi Standl.
P. zinggii Standl.
Rubus arizonensis Focke
R. neomexicanus A. Gray
R. parviflorus Nutt.
R. strigosus Michx.

SOLANACEAE - NIGHTSHADE FAMILY
Capsicum annuum L. var. *aviculare* (Dierb.) D'Arcy & Eshb.
Nicotiana obtusifolia Mart. & Gal.
N. plumbaginifolia Viviani
Physalis acutifolia (Miers) Sandw.
P. angulata L. var. *lanceifolia* (Nees) Waterf.
P. caudella Standl.
P. hederaefolia A. Gray var. *puberula* A. Gray
P. hypophila Standley
P. lagascae Roem. & Schult.
P. leptophylla Robins. & Greenm.
P. pruinosa L.
P. viscosa subsp. *mollis*
Solanum adscendens Mill.
S. americanum Mill.
S. azureum Fernald
S. candidum Lindl.
S. erianthum D. Don
S. fendleri A. Gray
S. ferrugineum Mart. & Gal.
S. geminiflorum Mart. & Gal.
S. grayi Rose var. *grayi*
S. jamesi Torr.
S. heterodoxum Dunal var. *heterodoxum*
S. lumholtzianum Bartlett
S. nigrescens Mart. & Gal.
S. refractum Hook. & Arn.
S. seaforthianum Andrews
S. tridynamum Dunal
S. umbellatum Mill.

VITACEAE - GRAPE FAMILY
Vitis arizonica Engelm.

Appendix 4. Examples of commonly used plants of economic importance.

AGAVACEAE - CENTURY PLANT FAMILY
Agave angustifolia Haw. var. *angustifolia*
A. palmeri Engelm.
A. vilmoriniana Berger
Dasylirion wheeleri S. Watson var. *durangense* (Trel.) Laferrière
D. wheeleri var. *wheeleri*
Hesperaloe nocturna Gentry
Nolina microcarpa S. Watson

APIACEAE (UMBELLIFERAE) - CARROT FAMILY
Eryngium heterophyllum Engelm.
Ligusticum porteri Coult. & Rose

ARECACEAE (PALMAE) - PALM FAMILY
Brahea aculeata (Brandegee) H. E. Moore
Sabal uresana Trel.

ASTERACEAE (COMPOSITAE) - ASTER FAMILY
Acourtia thurberi (A. Gray) Reveal & R.M. King
Cosmos parviflorus (Jacq.) Pers.
C. pringlei Robins. & Fernald
Iostephane heterophylla (Cav.) Hemsl.
I. madrensis (S. Watson) Strother
Lasianthaea podocephala (A. Gray) K. Becker
Parthenium tomentosum DC. var. *stramonium* (Greene) Rollins
Pectis stenophylla A. Gray
Psacalium decompositum (Robins. & Fernald) Robins. & Brett.
Senecio (*Packera*) *candidissimus* Greene
S. (*Roldana*) *sessilifolius* (Hook. & Arn.) Hemsl.
Tagetes filifolia Lag.
T. lucida Cav.
T. micrantha Cav.

BIGNONIACEAE - BIGNONIA FAMILY
Tabebuia chrysantha (Jacq.) Nichols.
T. impetiginosa (A. DC.) Standl.

BOMBACACEAE - SILK-COTTON FAMILY
Ceiba aesculifolia (H.B.K.) Britt. & Baker

BURSERACEAE - FRANKINCENSE FAMILY
Bursera penicillatus (DC.) Engler

CACTACEAE - CACTUS FAMILY
Opuntia engelmannii Engelm.
Opuntia spp.
Pachycereus pecten-aboriginum (Engelm.) Britt. & Rose
Stenocereus montanus (Britt. & Rose) Buxb.
S. thurberi (Engelm.) Buxb.

CARICACEAE - PAPAYA FAMILY
Jarilla chocola Standl.

CHENOPODIACEAE - GOOSEFOOT FAMILY
Chenopodium ambrosioides L.
C. graveolens Willd.

COCHLOSPERMACEAE - COCHLOSPERMUM FAMILY
Amoreuxia gonzalezii Sprague & Riley
A. palmatifida Ses. & Moç.

CONVOLVULACEAE - MORNING GLORY FAMILY
Ipomoea bracteata Cav.

CUCURBITACEAE - GOURD FAMILY
Cucurbita foetidissima H.B.K.

CUPRESSACEAE - CYPRESS FAMILY
Cupressus arizonica Greene
Juniperus deppeana Steud.
J. durangensis Martínez
Taxodium mucronatum Tenn.

EBENACEAE - PERSIMMON FAMILY
Diospyros sonorae Standl.

ERICACEAE - HEATHER FAMIY
Arbutus arizonicus (A. Gray) Sarg.
A. xalapensis Sarg.
Arctostaphylos pungens H.B.K.

EUPHORBIACEAE - SPURGE FAMILY
Croton cf. *niveus* Jacq.

FABACEAE (LEGUMINOSAE) - LEGUME FAMILY
Acacia cochliacantha Willd.
A. farnesiana (L.) Willd.
A. pennatula (Cham. & Schlecht.) Benth.
Brongniartia alamosana Rydb.
Caesalpinia platyloba S. Watson
Erythrina flabelliformis Kearney
Haematoxylum brasiletto Karst.
Lysiloma microphyllum Benth.
Phaseolus maculatus Scheele subsp. *maculatus* Freytag
P. maculatus subsp. *ritensis* (M.E. Jones) Freytag
P. salicifolius Piper
Pithecellobium dulce (Roxb.) Benth.
Platymiscium trifoliata Benth.
Prosopis glandulosa Torr. var. *torreyana* (L.D. Benson) M.C. Johnst.
P. velutina Woot.
Senna atomaria (L.) Irwin & Barneby
Zornia reticulata J.E. Smith

FAGACEAE - BEECH FAMILY
Quercus albocincta Trel.
Q. emoryi Torr.

LABIATAE (LAMIACEAE) - MINT FAMILY
Hedeoma patens M.E. Jones
Mentha arvensis L. var. *villosa* (Benth.) Stewart
Monarda citriodora Lag. subsp. *austromontana* (Epling) Scora

LAURACEAE - LAUREL FAMILY
Cinnamomum sp.

MELIACEAE - CHINABERRY FAMILY
Cedrela odorata L.

MORACEAE - MULBERRY FAMILY
Chlorophora tinctoria (L.) Benth. & Hook. f.
Ficus pertusa L. f.

MYRTACEAE - MYRTLE FAMILY
Psidium sartorianum (O. Berg) Ndzu.

PINACEAE - PINE FAMILY
Abies concolor (Gordon & Glend.) Hildebr.
A. durangensis Martínez
Pinus cembroides Zucc.
P. douglasiana Martínez
P. durangensis Martínez
P. edulis Engelm.
P. englemannii Carr.
P. herrerae Martínez
P. lumholtzii Robins. & Fernald
P. oocarpa Scheide
P. ponderosa Laws. & C. Laws. var. *arizonica* (Engelm.) Shaw
P. ponderosa var. *scopulorum* Engelm.
P. strobiformis Engelm.
Pseudostsuga menziesii (Mirb.) Franco var. *glauca* (Mayr) Franco

POACEAE (GRAMINEAE) - GRASS FAMILY
Bouteloua spp.
Eragrostis spp.
Hordeum pusillum Nutt.
Pennisetum karwinskii Schrader
Setaria spp.
Zea mays L. subsp. *mexicana* (Schrad.) Iltis

POLYGONACEAE - BUCKWHEAT FAMILY
Eriogonum atrorubens Engelm.
E. tenellum Torr.

ROSACEAE - ROSE FAMILY
Potentilla thurberi A. Gray
Prunus gentryi Standl.
P. serotina Ehrh. subsp. *capuli* (Cav.) McVaugh
P. serotina subsp. *virens* (Woot. & Standl.) McVaugh
P. zinggii Standl.

RUBIACEAE - RUE FAMILY
Hintonia latiflora (Ses. & Moç.) Bullock
Randia echinocarpa Ses. & Moç.

SAPINDACEAE - SOAPBERRY FAMILY
Sapindus saponaria L.

SAPOTACEAE - SAPOTE FAMILY
Sideroxylon capiri (A. DC.) Pitt. subsp. *tempisque* (Pitt.) T.D. Penn.
S. persimile (Hemsl.) T.D. Penn. subsp. *subsessiliflorum* (Hemsl.) T.D. Penn.
S. tepicense (Standl.) T.D. Penn.

SOLANACEAE - NIGHTSHADE FAMILY
Capsicum annuum L. var. *aviculare* (Dierb.) D'Arcy & Eshb.
Datura lanosa Bye
Jaltomata procumbens (Cav.) Gentry
Solanum fendleri A. Gray
S. jamesii Torr.

STERCULIACEAE - STERCULIA FAMILY
Guazuma ulmifolia Lam.

VERBENACEAE - VERBENA FAMILY
Lippia graveolens H.B.K.
L. palmeri S. Watson
Vitex mollis H.B.K.