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## Southwest Region

Steven J. Seybold, Andrew D. Graves, Susan J. Frankel, Allen White, Carol A. Sutherland, and A. Steve Munson

### Introduction

The Southwest region (Arizona, California, Colorado, Nevada, New Mexico, and Utah) (Figs. A4.1 and A4.2) is marked by Mediterranean, montane, and desert climates/ecosystems that provide unique and amenable conditions and habitats for invading plants, pathogens, insects, and vertebrates. Aridity is perhaps the dominant climatic feature framing the forest ecosystems of the Southwest (Peterson 2012). Extreme elevational gradients and the intervening desert landscapes in this region (Fig. A4.2) create pronounced biogeographical boundaries and refugia for endemic species of plants and animals. The southern edge of this region has an extensive, but ecologically contiguous, border with Mexico that facilitates biological invasions. Future climate conditions projected for the southern portion of this region predict a trend of increasing temperature and decreasing precipitation (Cayan et al. 2010; Peterson 2012; Williams et al. 2010). Changing climate will likely place water stress on native trees and other plants, perhaps accelerating the establishment of invasive species (Peterson 2012) and amplifying outbreaks of native pest species (Breshears et al. 2005). These changes may also facilitate the spread of invasive species northward across this international border (e.g., Billings et al. 2014; Moser et al. 2005). The rate of spread of invasive species across this border may be increased by instances of unregulated movement of humans and cargo.

This region also features a wide range of non-native ornamental plants in urban and rural areas, enormously productive and diverse agroecosystems, and huge tracts of public lands with grazing impacts that favor the establishment and spread of invasive plants and pathogens by wild and domestic ungulates and other animals. High property values and residences in and near this region's forests make the impacts of invasive species particularly expensive and difficult to manage, as they often range across varied and numerous land ownerships. From a sociological perspective, the diverse human population of the region provides linkages to many overseas source populations of invasive species, whereas numerous maritime and overland ports-of-entry as well as U.S. and international tourism in response to the attractive natural features and mild winter climate may also enhance the introduction, establishment, and spread of invading organisms.

### Plants

Terrestrial invasive plants in the Southwest region include annual, biennial, and perennial species of grasses, forbs,

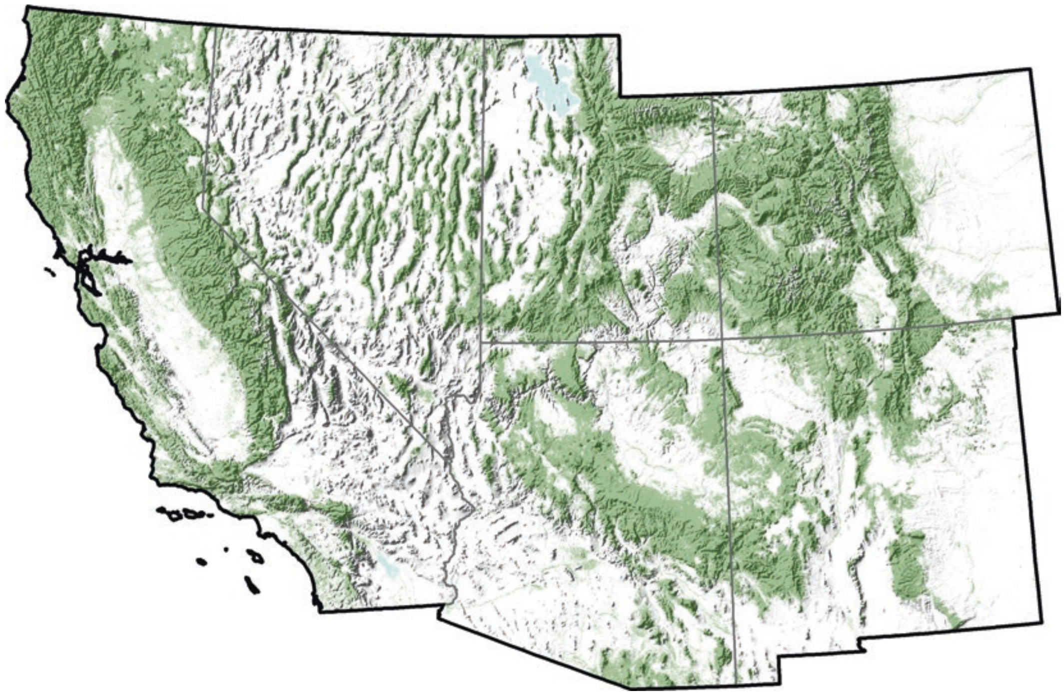

**Fig. A4.1** The Southwest region

**Fig. A4.2** The Southwest region of the United States includes Arizona, California, Colorado, Nevada, New Mexico, and Utah


shrubs, and trees (Table A4.1). Although some of these plants (e.g., Chinese elm (*Ulmus parvifolia*), Siberian elm (*U. pumila*), and saltcedar (*Tamarix* spp.)) were considered previously as desirable landscaping materials, these and a variety of other species are listed by Southwestern States as noxious weeds, which by statutory regulation require landowners to manage them. However, these species are typically quite difficult to manage once established, and control generally requires repetitions of a variety of separate treatments over a period of years. Availability of financial resources for costly suppression/eradication efforts can also be an impediment. In some cases, only biological control agents (if available)

**Table A4.1** The primary invasive plants of the Southwest region include brooms, grasses, knapweeds, thistles, and several trees

| | | Occurrence | | | | | | Impacts/potential impacts | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scientific name | Common name | AZ | CA | CO | NV | NM | UT | Native biodiversity | Land values | Recreation | Fire risk/ ecosystem conversion | Grazing |
| *Acroptilon repens* (L.) DC. | Russian knapweed | x | x | x | x | X | x | • | • | | | • |
| *Aegilops cylindrica* Host | Jointed goatgrass | x | x | x | x | X | x | • | • | | | |
| *Alhagi pseudalhagi* (M.Bieb.) Desv. ex B. Keller & Shap. | Camelthorn | x | x | x | x | X | x | | | | | • |
| *Bothriochloa bladhii* (Retz.) S.T. Blake | Caucasian bluestem | | | | | X | | • | | | | |
| *Bothriochloa ischaemum* (L.) Keng | Yellow bluestem | | | | | x | | • | | | | |
| *Bromus tectorum* L. | Downy brome, cheatgrass | x | x | x | x | x | x | • | • | • | • | • |
| *Cardaria draba* (L.) Desv. | Hoary cress, whitetop | x | x | x | x | x | x | • | • | | | • |
| *Carduus nutans* L. | Musk thistle | x | x | x | x | x | x | • | | | | • |
| *Centaurea diffusa* Lam. | Diffuse knapweed | x | x | x | x | x | x | • | | | | • |
| *Centaurea melitensis L.* | Maltese starthistle | | | | x | x | | • | • | | | • |
| *Centaurea stoebe* L. spp. *micranthos* (Gugler) Hayek syn. *C. maculosa* auct. non Lam. | Spotted knapweed | x | x | x | x | x | x | • | | | | • |
| *Centaurea solstitialis* L. | Yellow starthistle | x | x | x | x | x | x | • | • | • | | • |
| *Centaurea virgata* Lam. ssp. *squarrosa* (Willd.) Gugler | Squarrose knapweed | x | x | | x | | x | • | | | | • |
| *Chondrilla juncea* L. | Rush skeletonweed | x | x | x | x | | x | • | • | | | • |
| *Cirsium arvense* (L.) Scop. | Canada thistle | x | x | x | x | x | x | • | | | | • |
| *Cynoglossum officinale* L. | Houndstongue | x | x | x | x | x | x | • | | | | • |
| *Cytisus scoparius* (L.) | Scotch broom | | x | | | | x | • | | | • | |
| *Elaeagnus angustifolia* L. | Russian olive | x | x | x | x | x | x | • | | • | | |
| *Euphorbia esula* L. | Leafy spurge | x | x | x | x | x | x | • | • | | | • |
| *Genista monspessulana* (L.) L.A.S. Johnson | French broom | | x | | | | | • | | | • | • |
| *Halogeton glomeratus* (M. Bieb.) C.A. Mey. | Halogeton | x | x | x | x | x | x | | | | | • |
| *Hyoscyamus niger* L. | Black henbane | | | x | x | x | x | | | | | • |
| *Hydrilla verticillata* (L. f.) Royle | Hydrilla, Florida elodea | x | x | | | | | • | | • | | |
| *Isatis tinctoria* L. | Dyer's woad | x | x | x | x | x | x | • | | | | • |
| *Lepidium latifolium* L. | Perennial pepperweed | x | x | x | x | x | x | • | • | | | • |
| *Linaria dalmatica* L. | Dalmatian toadflax | x | x | x | x | x | x | • | | | | • |
| *Linaria vulgaris* Mill. | Yellow toadflax | x | x | x | x | x | x | • | | | | • |
| *Lythrum salicaria* L. | Purple loosestrife | x | x | x | x | x | x | • | | | | |

(continued)

**Table A4.1** (continued)

| Scientific name | Common name | Occurrence | | | | | | Impacts/potential impacts | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AZ | CA | CO | NV | NM | UT | Native biodiversity | Land values | Recreation | Fire risk/ ecosystem conversion | Grazing |
| *Onopordum acanthium* L. | Scotch thistle | x | x | x | x | x | x | • | | | | • |
| *Peganum harmala* L. | African rue, Syrian rue | x | x | x | x | x | | | | | | • |
| *Pennisetum ciliare* (L.) Link | Buffelgrass | x | x | | | x | x | • | | | • | |
| *Phragmites australis* ssp. *australis* (Cavanilles) Trinius ex Steudel | European common reed | x | x | x | x | x | x | • | • | • | | |
| *Salvinia molesta* Mitchell | Giant salvinia | x | x | | | | | • | | • | | |
| *Sorghum halepense* (L.) Pers. | Johnsongrass | x | x | x | x | x | x | | | | | • |
| *Taeniatherum caput-medusae* (L.) Nevski | Medusahead | x | x | | x | | x | • | | | • | • |
| *Tamarix* spp. L. | Saltcedar | x | x | x | x | x | x | • | | | • | |

This list was compiled by comparing noxious weed lists of the individual States in the Southwest region (USDA National Resources Conservation Service 2018). Invasive plants that appeared in four or more State lists were included in this table. Distributions for the invasive plants were validated by using EDDMapS (2019). Additional invasive plants that may have occurred in fewer than four regional States were included if local vegetation specialists deemed them to be particularly significant. This list was compiled by Andrew D. Graves and Allen White, USDA Forest Service, Forest Health Protection, Albuquerque, NM, and Richard D. Lee, Ph. D., integrated pest management specialist, U.S. Department of the Interior Bureau of Land Management, Denver, CO

can effectively impact infestations of invasive plant species that have spread extensively over entire landscapes. Several prominent invasive plant species found in the Southwest region are discussed below.

Among the invasive plant species, buffelgrass (*Pennisetum ciliare*) is the single greatest threat to desert ecosystems in the warmer latitudes of the Southwest region (Fig. A4.3a) (USDA FS Southwestern region 2017). Buffelgrass is an invasive bunchgrass from tropical and subtropical arid regions of Africa and Western Asia that was developed in the United States as a drought-tolerant forage grass (Marshall et al. 2012). The perennial species was first planted successfully in Texas in the 1940s for forage and in Arizona in the 1950s to stabilize soils (Marshall et al. 2012); however, it now threatens the Sonoran Desert ecosystem through its expansion into southern Arizona and most of Sonora, Mexico. The northward expansion is currently limited by the relative cold intolerance of buffelgrass; however, regional temperature increases predicted as a consequence of climate change may allow expansion to continue further north and into higher mountain elevations. Although buffelgrass seed is spread long distances by wind, vehicles, and other means, individual patches of buffelgrass can double in place every 2–7 years (Olsson et al. 2012). Buffelgrass can outcompete native desert vegetation for water, nutrients, and sunlight. It also forms dense infestations that allow fires to spread across the landscape on a cyclical basis. The Sonoran Desert evolved without fire, and most native plant species in the desert such as the iconic saguaro cactus (*Carnegiea gigantea*) are fire-intolerant. Consequently, the buffelgrass invasion of the Sonoran Desert is effectively transforming large portions of the desert ecosystem into fire-prone tropical savanna.

Also of concern is musk thistle (*Carduus nutans*), which is a spiny invasive weed in the sunflower family (Asteraceae) with highly branched stems and purplish-red disk flowers (Fig. A4.3b). The flowers "nod" at a 90-degree angle, hence its alternate common name, "nodding" thistle. The species is highly competitive and rapidly invades rangeland, roadsides, and disturbed sites in the Southwest. Musk thistle seed is readily dispersed by wind, water, birds, and other animals. In addition, seed can be carried over long distances by adhering to the surfaces of vehicles and road maintenance equipment. These invasive features make musk thistle difficult to control. A biological control agent, thistle seedhead weevil (*Rhinocyllus conicus* (Coleoptera: Curculionidae)), was imported and released in the United States between 1969 and 1972 to control musk thistle along with other thistles (Louda et al. 1997; Winston et al. 2014a). However, the establishment and expansion of the distribution of the seedhead weevil from early-release sites enabled the weevil to also encounter and attack many native thistles (Louda et al. 1997), including the endangered Sacramento Mountain thistle (*Cirsium vinaceum*) in southern New Mexico. Consequently, interstate shipments of the weevil are no longer permitted by the USDA Animal and Plant Health Inspection Service (APHIS) (Winston et al. 2008).

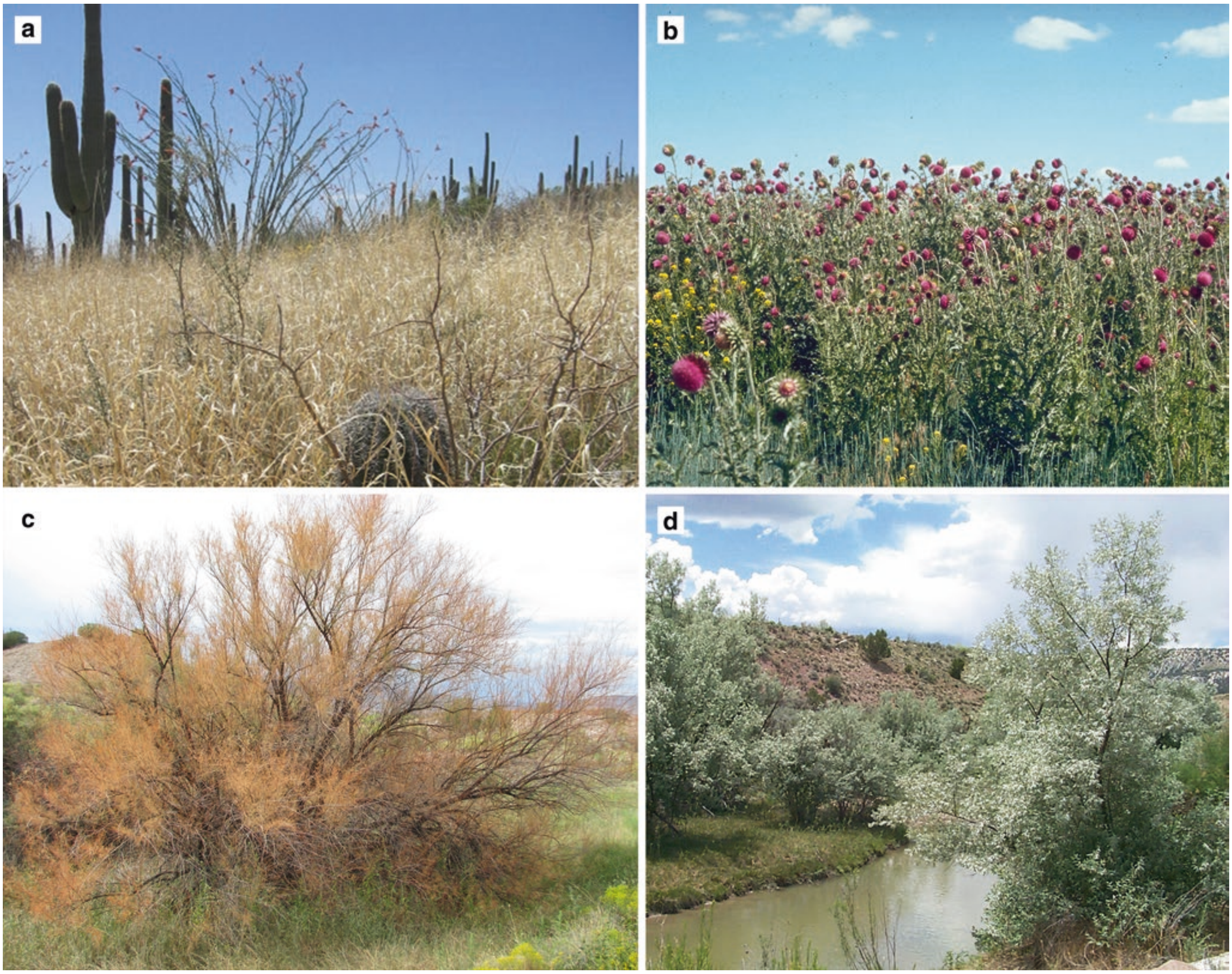

**Fig. A4.3** Invasive plants associated with Arizona and New Mexico include (**a**) buffelgrass (*Pennisetum ciliare*) (photo credit: U.S. Department of the Interior, National Park Service); (**b**) musk thistle (*Carduus nutans*) (photo credit: Norman E. Rees, USDA Agricultural Research Service); (**c**) defoliated saltcedar (*Tamarix* sp.) (photo credit: Debra Allen-Reid, retired, USDA Forest Service, Forest Health Protection, Albuquerque, NM); and (**d**) Russian olive (*Elaeagnus angustifolia*). (Photo credit: J. Scott Peterson, USDA Agricultural Research Service)

One of the most widely dispersed invasive plant species in the Southwest region is saltcedar (*Tamarix* spp.), which occurs frequently as either a shrub or small tree in thick stands along waterways (Fig. A4.3c). Saltcedar can affect riparian systems by altering stream flow (via evapotranspiration) and ecological processes (e.g., soil salinization and microbial activity). However, some detrimental effects attributed to the species such as excessive evapotranspiration may have been overestimated (Glenn and Nagler 2005). Beginning in 2001, four species of the tamarisk leaf beetle (*Diorhabda* spp. (Coleoptera: Chrysomelidae)), from North Africa, the Mediterranean, and Asia were released in several Western US States as a host-specific biocontrol agent (Moran et al. 2009). Both adult tamarisk leaf beetles and larvae damage saltcedar foliage, which can progressively weaken or kill the plant over a period of several years. Since their release, species of *Diorhabda* have spread and are now found in 11 Western US States with pronounced recoveries of the beetle in the major watersheds of eastern Utah, western Colorado, northern Arizona, and New Mexico (Fig. A4.4). Although APHIS no longer issues permits for transporting *Diorhabda* beetle species across state borders (USDA APHIS 2010), beetle spread is expected to continue naturally and possibly by human assistance within individual Western States (Bloodworth et al. 2016). Areas with defoliated or dead saltcedar may eventually allow native plant species such as cottonwood (*Populus* spp.), or willow (*Salix* spp.), to return; however, defoliated saltcedar sites may also be invaded by other weedy plant species, some of which may be even more undesirable and difficult to manage than saltcedar. In addi-

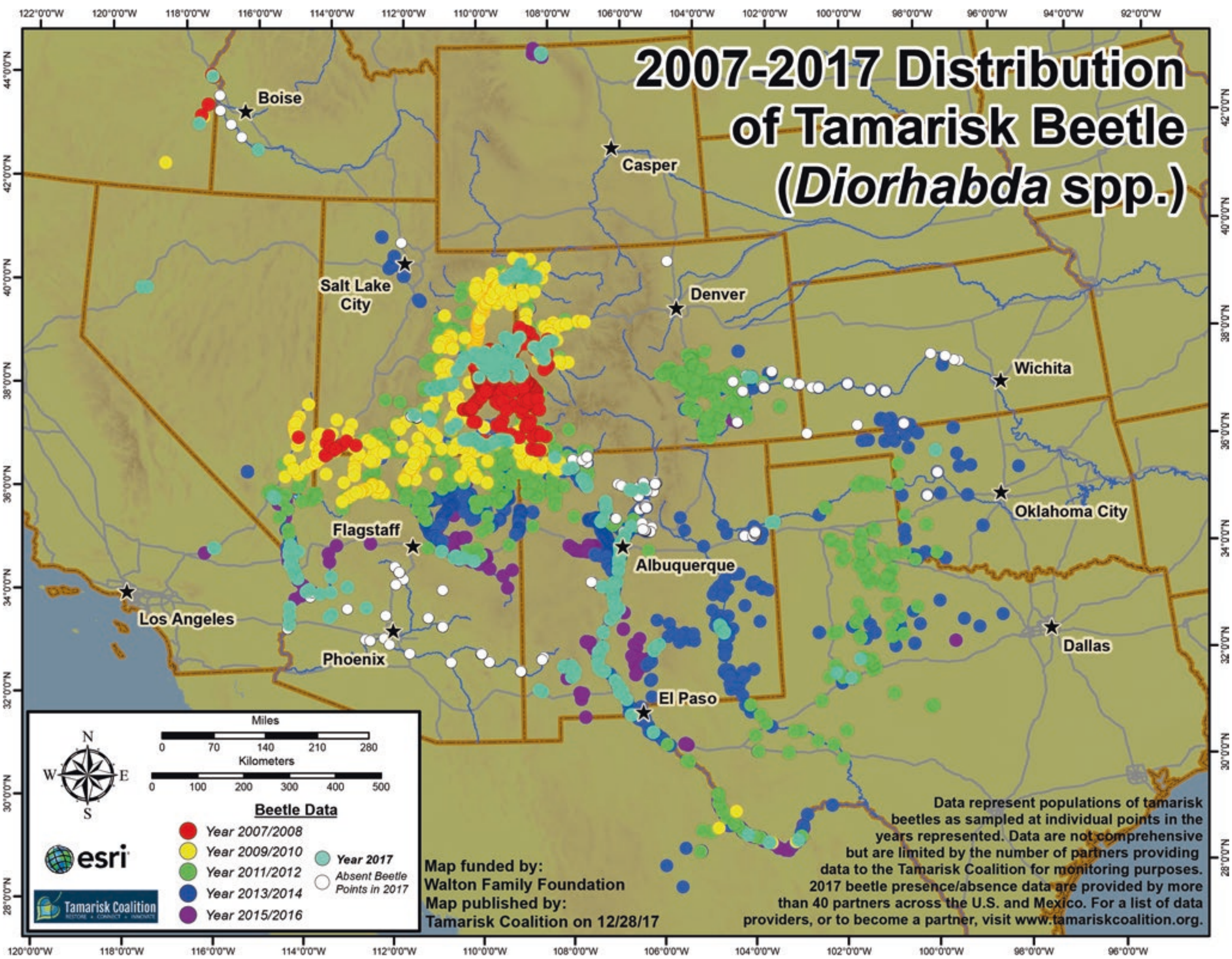


**Fig. A4.4** An 11-year record of the distribution of tamarisk beetles (*Diorhabda* spp.), in the Southwest region. Four species of this beetle were introduced in 2001 to provide biological control of invasive saltcedar (*Tamarix* spp.), in the region. Further facilitation of the spread of the beetles was curtailed when it became evident that saltcedar mortality threatened nesting habitat used by the endangered southwestern willow flycatcher (*Empidonax traillii extimus*). In 2016–2017, the Gila (southern Arizona and New Mexico) and Arkansas (southern Kansas) watersheds have been scrutinized intensively for potential newly established populations of *Diorhabda* spp. (Map courtesy of B. Bloodworth (Tamarisk Coalition 2017))

tion, the expanding distribution of *Diorhabda* species threatens nesting habitat used by the endangered southwestern willow flycatcher (*Empidonax traillii extimus*), which nests in saltcedar-dominated plant communities that have replaced native cottonwood and willow species. Large-scale defoliations of tamarisk may cause a temporary loss in flycatcher habitat for at least a decade before the native cottonwoods and willows can return (Paxton et al. 2011).

Over the past century, Russian olive (*Elaeagnus angustifolia*) was planted widely throughout the United States as an ornamental and windbreak tree, but it has since escaped into natural areas of the Southwest region (Fig. A4.3d) (Katz and Shafroth 2003). It is a hardy, fast-growing, deciduous tree with silvery, gray-green leaves, growing to a height of about 10 m. Along with saltcedar, this invasive tree species serves as potential nesting habitat for the southwestern willow flycatcher. Russian olive seed is eaten by birds, and bird droppings with the seed contribute greatly to the tree's spread. The ovoid fruit floats on water and is readily dispersed along waterways. After invasion, Russian olive can become the dominant species in areas due to its adaptability, prolific reproduction, rapid growth rate, and lack of natural enemies. As infestations expand, Russian olive crowds out desirable native riparian trees such as cottonwoods and willows, thereby reducing floral and faunal diversity. Because of its ability to colonize stream banks, the species can alter the natural flooding regime and reduce availability of nutrients and moisture. It is extremely difficult to restore native plant communities once Russian olive has established dense, monotypic stands. The primary tools that land managers have for controlling these trees include repeated bulldozing, root plowing, cut-stump herbicide treatments, or prolonged flooding. These tools may also be used for controlling saltcedar (see above). Based on entomological literature from Asia, there was speculation that Russian olive in the Western United States might serve as a host for the invasive banded elm bark beetle (*Scolytus schevyrewi*) (see below), but there have been no observations or experimental evidence in the United States to substantiate this hypothesis (Lee et al. 2011; Negrón et al. 2005).

In California, the highest-priority noxious weeds include yellow starthistle (*Centaurea solstitialis*), several knapweeds (spotted knapweed (*C. stoebe*), diffuse knapweed (*C. diffusa*), meadow knapweed (*C. debeauxii*)), perennial pepperweed (*Lepidium latifolium*), thistles ((bull thistle (*Cirsium vulgare*), Scotch thistle (*Onopordum acanthium*), musk thistle (*Carduus nutans*), Canada thistle (*Cirsium arvense* and others)), and brooms (Scotch broom (*Cytisus scoparius*) and French broom (*Genista monspessulana*)). More information on these and over 200 California invasive plants is maintained in the California Invasive Plant Council (Cal-IPC) Inventory (CaL-IPC 2006). The northern tier of States in the Southwest region (Colorado, Nevada, and Utah) represent a relatively large landscape, and the most problematic invasive plants vary depending on local conditions (Table A4.1). As a functional group, invasive annual grasses such as cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*) (Table A4.1) impact native plant communities in these northern tier states, as well as in California. They are responsible for landscape-scale conversion of native vegetation to annual grassland in the Great Basin sagebrush steppe and in California grasslands and sage scrub (see Chap. 2, Sects. 2.2.2 and 2.2.3, for more details and discussion of interactions of these regional invasive grasses with fire and pollinators).

Of emerging concern in the Southwest region are two invasive bunchgrass species, yellow bluestem (*Bothriochloa ischaemum*) and Caucasian bluestem (*B. bladhii*). These two bunchgrass species are part of a global complex of invasive bluestem species collectively called Old World bluestems to differentiate them from North American bluestem species. The two bunchgrass species were originally imported from Eurasia and Africa for erosion control and as forage crops (Klataske 2016; Missouri Department of Conservation 2010). These extremely persistent plants form monocultures that can lower biodiversity in native grassland and pastures (Gabbard and Fowler 2007; Klataske 2016). Yellow and Caucasian bluestems have become invasive in pastures and native grasslands of states in the Midwest and the Southern Great Plains (Oklahoma, Texas, and eastern New Mexico). An informal survey conducted by the USDA Forest Service in 2017 indicated that yellow bluestem is present along roadsides on most national forests and national grasslands in the Forest Service's Southwestern Region (Region 3). Caucasian bluestem has also been found on the Coconino National (Agyagos 2018).

### Plant Pathogens

In the Southwest region, invasive plant pathogens (Table A4.2) are a significant problem in both urban and rural forests with their impacts dependent on the outbreak location and the attributes of the particular host tree species. Below is a short regional overview of the most damaging invasive pathogens; notably, most of these pathogens have been introduced on imported nursery stock (Liebhold et al. 2012).

White pine blister rust (*Cronartium ribicola*) is killing white (five-needle) pines in all states in the Southwest region including commercial species (i.e., sugar pine (*Pinus lambertiana*) and southwestern white pine (*P. strobiformis*)) and high-elevation pines (limber (*P. flexilis*), whitebark (*P. albicaulis*), foxtail (*P. balfouriana*), western white (*P. monticola*), and bristlecone (*P. aristata* and *P. longaeva*)) (Geils et al. 2010, Fig. A4.5). White pine blister rust is among the most damaging of invasive pathogens in U.S. forests and parks (Benedict 1981; Boyce 1938; Vitousek et al. 1996). The rust, native to Asia, was introduced around 1910 to Western North America near Vancouver, British Columbia, Canada, on nursery stock from France (Liebhold et al. 2012). The 1912 Plant Quarantine Act was a direct result of its introduction, with U.S. Quarantine No. 1 prohibiting importation of five-needle pines (Maloy 1997). The distribution of *C. ribicola* continues to expand southward in California, but the pathogen has not yet moved into and past the Tehachapi Mountains in the Transverse Ranges of southern California (Smith 2018).

A more recent invader, *Phytophthora ramorum*, which is the pathogen associated with sudden oak death, has become the number one cause of tree mortality in California coastal forests (see Chap. 2, Box 2.5; Chap. 6, Sect. 6.4.2; Chap. 7, Sect. 7.4.2; and the Northwest region summary for additional discussion of this pathogen). The pathogen kills tanoak (*Notholithocarpus densiflorus*), coast live oak (*Quercus agrifolia*), and other red oaks. It is also known to infect over 100 other plant species including conifers, herbaceous plants, and ferns. The pathogen is estimated to have been introduced in California sometime around 1980 on rhododendron (*Rhododendron* spp.) nursery stock (Mascheretti et al. 2008) and has since killed millions of trees along the Pacific Coast (California Central Coast north to Curry County, OR). The tree mortality increased dramatically in the late 1990s in the San Francisco Bay Area where over six million people reside, making the management of hazards (dead trees and branches) in residential areas, as well as along roadways and power lines, a chronic issue. The pathogen is also of particular concern to Native American tribes, since they rely on acorns for ceremonies and food

**Table A4.2** The primary invasive plant and animal pathogens of the Southwest region include bacteria, fungi, prions, and viruses

| | | Occurrence | | | | | | References |
|---|---|---|---|---|---|---|---|---|
| Scientific name | Common name | AZ | CA | CO | NV | NM | UT | |
| *Batrachochytrium dendrobatidis* | Amphibian chytrid fungus (*Bd*) | X | X | X | X | X | X | http://www.bd-maps.net/ |
| *Candidatus* Liberibacter asiaticus | Citrus Huanglongbing | | X | | | | | Kumagai et al. (2013) and McCollum and Baldwin (2017) |
| *Chronic wasting disease prion* | Chronic wasting disease (CWD) | | | X | | X | X | https://www.cdc.gov/prions/cwd/occurrence.html |
| *Cronartium ribicola* | White pine blister rust | X | X | X | X | X | X | Geils et al. (2010) |
| *Fusarium circinatum* | Pitch canker | | X | | | | | Gordon et al. (2001), Gordon (2016), and Wingfield et al. (2008) |
| *Fusarium euwallaceae* | Fusarium decline | | X | | | | | Eskalen et al. (2013) and Lynch et al. (2016) |
| *Geosmithia morbida* | Thousand cankers disease pathogen | X | X | X | X | X | X | Kolařík et al. (2011, 2017) and Tisserat et al. (2011) |
| *Melampsora larici-populina* | Eurasian poplar leaf rust | | X | | | | | Farr and Rossman (2018) and Pinon et al. (1994) |
| *Phytophthora lateralis* | Port-Orford-cedar root disease | | X | | | | | https://www.cabi.org/isc/datasheet/40973 |
| *Phytophthora ramorum* | Sudden oak death | | X | | | | | http://www.suddenoakdeath.org |
| *Pseudogymnoascus destructans* | White-nose syndrome | | | X | | | | https://www.whitenosesyndrome.org/mmedia-education/july-2-2018 |
| *Puccinia graminis* | Black stem rust | x | X | X | | X | X | https://www.cabi.org/isc/datasheet/45797;<br>Farr and Rossman 2018 |
| *Ranavirus* | Ranavirus | X | X | X | X | X | X | https://cwhl.vet.cornell.edu/disease/ranavirus |

**Fig. A4.5** White pine blister rust is caused by infection of five-needle pines with *Cronartium ribicola*, which is an invasive pathogen that continues to expand its range in the Southwest. The image shows a white pine blister rust canker with aeciospores on southwestern white pine (*Pinus strobiformis*), on the Lincoln National Forest in southeastern New Mexico. (Photo credit: James Jacobs, USDA Forest Service, Forest Health Protection, Albuquerque, NM)

(Long and Goode 2017; Long et al. 2017) and consider the primary host tree species to be sacred (Alexander and Lee 2010).

Of special concern in the Southwest region are invasive pathogens that impact tree species of limited native distribution. Monterey pines (*Pinus radiata*) along the California Central Coast are dying in large numbers from pitch canker, caused by *Fusarium circinatum*, in combination with drought and colonization by bark and twig beetles. Pitch canker was first observed in California in Santa Cruz County in 1986 (Gordon et al. 2001; McCain et al. 1987; Wingfield et al. 2008). Monterey pine mortality has been prevalent in adventive stands along highways and roadsides, but the three largest native forests of Monterey pine in the world are all infested and severely damaged (Wikler et al. 2003). Another invasive species of *Fusarium* (*F. euwallaceae*), in tandem with an invasive ambrosia beetle species complex (see below), threatens native riparian hardwood trees in southern California (Coleman et al. 2013; Eskalen et al. 2013).

Native endemic riparian walnut trees (southern California walnut (*Juglans californica*) and northern California walnut (*J. hindsii*) in California) (Flint et al. 2010; Griffin and Critchfield 1972) and adventive black walnut trees (*J. nigra*) in Colorado and Utah (Tisserat et al. 2011) have been recorded with crown dieback and tree mortality from thousand cankers disease, caused by a newly described fungus, *Geosmithia morbida* (Kolařík et al. 2011, 2017), vectored by the walnut twig beetle (*Pityophthorus juglandis* (Coleoptera: Scolytidae)) (Seybold et al. 2016, 2019). Over 60% (1300 trees) of the black walnut growing in Boulder, CO had to be removed between 2004 and 2010 in response to this disease (Tisserat et al. 2011). Between 2010 and 2014 in survey plots in California, nearly 10% of the trees died in one native stand each of southern California walnut and northern California walnut, whereas levels of infection reached 90–100% for a range of walnut species in a northern California germplasm collection (Hishinuma 2017). The native range of the beetle (Rugman-Jones et al. 2015) and, likely, the fungal pathogen (Zerillo et al. 2014) are sympatric with the northern portion of the distribution of Arizona walnut (*J. major*) (USDA NRCS 2018). In stands of this putative ancestral host of the beetle and pathogen, Graves et al. (2011) reported 6.7% mortality and approximately 50% infection/infestation in national forest survey plots in Arizona and New Mexico.

Nearly the entire native range of Port-Orford-cedar (*Chamaecyparis lawsoniana*) is infested with *Phytophthora lateralis,* an invasive pathogen that causes a lethal root disease (see Northwest regional summary for additional discussion of this pathogen). The tree grows naturally along the Pacific Coast from northern California to southern Oregon but is also a prized ornamental. The pathogen was introduced on nursery stock near Seattle, WA, in the 1920s and spread southward on ornamental plantings until it reached the native stands in 1952. *Phytophthora lateralis* is thought to be native to Asia (Brasier et al. 2010). Once established, the pathogen moves via transport of infested soil on vehicle tires and in infested runoff water. To manage the pathogen, resistant trees have been developed, and, in some instances, local forest roads are closed during the wet season (Hansen et al. 2000).

### Insects

Much of the vast Southwest region has not been invaded by non-native forest insects (Table A4.3) (Furniss and Carolin 1977). The incidence of introduction and establishment is far higher in the Eastern United States (Liebhold et al. 2013). However, a recent survey has revealed that at least 22 species of invasive bark and ambrosia beetles (Coleoptera: Scolytidae) have established populations in California (Seybold et al. 2016). As a group, these main stem infesting pests are ranked among the most damaging to the growth and reproduction of trees (Mattson et al. 1988). Many of the spe-

**Table A4.3** The primary invasive insects of the Southwest Region include termites, beetles, flies, true bugs and other sucking insects, thrips, ants, wasps, and moths

| Scientific name | Common name | Occurrence | | | | | | References |
|---|---|---|---|---|---|---|---|---|
| | | AZ | CA | CO | NV | NM | UT | |
| **Isoptera** | | | | | | | | |
| *Coptotermes formosanus* | Formosan subterranean termite | | x | | | | | Rust et al. (1998) |
| *Cryptotermes brevis*[a] | Powderpost termite | | x | | | | | Evans et al. (2013), Light (1936), and Rust (2004) |
| **Coleoptera** | | | | | | | | |
| *Agrilus auroguttatus*[b] | Goldspotted oak borer | O | x | | | | | Coleman and Seybold (2016) |
| *Agrilus cuprescens* | Rose stem girdler | x | x | x | x | x | x | Cranshaw et al. (1994) |
| *Agrilus anxius*[b] | Bronze birch borer | | x | x | x | | | Carlos et al. (2002), Cranshaw et al. (1994), and Duckles and Švihra (1995) |
| *Agrilus planipennis* | Emerald ash borer | | | x | | | | Colorado State Forest Service (2018) |
| *Agrilus prionurus*[b] | Mexican soapberry borer | | | | | | | Billings et al. (2014) and USDA (2019) (in Texas) |
| *Amphimallon majale* | European chafer | | | | | x | | C. Sutherland, personal observation |
| *Anobium punctatum* | Furniture beetle | | x | | | x | | White (1982) |
| *Anoplophora glabripennis*[a] | Asian longhorned beetle | | x | | | | | Bohne (2007,2008) and Bohne and Rios (2006) |
| *Arhopalus syriacus* | | | x | | | | | Seybold et al. (2016) |
| *Brachypterolus pulicarius* | Toadflax flower-feeding beetle | | | x | x | | x | Sing et al. (2016) |
| *Chrysolina hyperici* | | | | | | | x | Winston et al. (2014a) |
| *Chrysolina quadrigemina* | Klamathweed beetle | | x | x | | | x | Winston et al. (2014a) |
| *Chrysophtharta m-fuscum* | A chrysomelid leaf beetle of eucalyptus | | x | | | | | Paine (2016) |
| *Coccinella septempunctata* | Seven-spotted lady beetle | | | | | x | | C. Sutherland, personal observation |
| *Coccotrypes advena* | A date palm seed beetle | | x | | | | | Seybold et al. (2016) |
| *Coccotrypes carpophagus* | A date palm seed beetle | | x | | | | | Rabaglia et al. (2019) and Seybold et al. (2016) |
| *Coccotrypes dactyliperda* | A date palm seed beetle | x | x | | | | | Seybold et al. (2016) |
| *Coccotrypes rutschuruensis* | A date palm seed beetle | | x | | | | | Atkinson (2018) |
| *Coniatus splendidulus* | Saltcedar bud weevil | x | x | x | x | x | x | Bright et al. (2013), C. Sutherland, personal observation, and Winston et al. (2014a) |
| *Cryptorhynchus lapathi* | Poplar-and-willow borer | | | x | | | x | Anderson (2008), Cranshaw et al. (1994), and USDA (2019) |
| *Curculio caryae*[b] | Pecan weevil | | | | | x | | Mulder et al. (2012) and Sutherland et al. (2017) |
| *Cyclorhipidion bodoanum* | | | x | x | | | | Atkinson (2018), Rabaglia et al. (2019), and Seybold et al. (2016) |
| *Dactylotrypes longicollis* | A palm seed beetle | | x | | | | | Seybold et al. (2016) |
| *Dinapate wrightii*[b] | Giant palm borer | x | O | | x | | x | Ivie (2002) and Olson (1991) (also introduced in Texas) |
| *Dinoderus minutus* | A bamboo borer | | x | | | | | Ivie (2002) and Spilman (1982) |
| *Diorhabda* spp. *D. carinata, carinulata, elongata, sublineata* | Tamarisk (saltcedar) leaf beetles | x | x | x | x | x | x | Tamarisk Coalition (2017) and Winston et al. (2014a) |
| *Ernobius mollis* | European bark anobiid | | x | | | | | Seybold and Tupy (1993) and Seybold (2001) |
| *Eustenopus villosus* | Yellow starthistle hairy weevil | | x | | | x | x | C. Sutherland, personal observation and Winston et al. (2014a) |
| *Euwallacea* sp. | Polyphagous and Kuroshio shot hole borers | | x | | | | | CFPC (2013), Chen et al. (2017), Seybold et al. (2016), and Umeda et al. (2016) |
| *Exapion fuscirostre* | Scotch broom weevil | | x | | | | | Andreas et al. (2017), EDDMapS (2019), and Winston et al. (2014b) |
| *Exapion ulicis* | Gorse seed weevil | | x | | | | | Andreas et al. (2017(, EDDMapS (2019), and Winston et al. (2014b) |
| *Gonipterus scutellatus* | Eucalyptus snout beetle | | x | | | | | Paine (2016) |
| *Harmonia axyridis* | Multicolored Asian lady beetle | x | x | x | x | x | x | C. Sutherland, personal observation and Mizell (2012) |

(continued)

**Table A4.3** (continued)

| Scientific name | Common name | Occurrence | | | | | | References |
|---|---|---|---|---|---|---|---|---|
| | | AZ | CA | CO | NV | NM | UT | |
| *Heterobostrychus brunneus* | | | x | | | | | Ivie (2002) |
| *Hylastes opacus* | European bark beetle | | x | | | | x | Atkinson (2018), Rabaglia et al. (2019), and USDA (2019), Also occurs in Texas |
| *Hylastinus obscurus* | Clover bark beetle | | x | | | | x | Wood and Bright (1992) |
| *Hylurgus ligniperda* | Red-haired pine bark beetle | | x | | | | | Liu et al. (2007) and Seybold et al. (2016) |
| *Hypothenemus californicus* | | | x | | | | | Wood and Bright (1992) |
| *Hypothenemus crudiae* | | | x | | | | | Rabaglia et al. (2019) |
| *Hypothenemus eruditus* | | | x | | | | | Seybold et al. (2016) |
| *Icosium tomentosum* | | | x | | | | | Bohne (2007) |
| *Ips calligraphus*[b] | Sixspined ips | O | x | O | | O | O | Seybold et al. (2016) Invasive in California, native elsewhere in Southwest region |
| *Lasioderma serricorne* | Cigarette beetle | x | x | x | x | x | x | CABI (2018), Phillips (2002), USDA (1986), and White (1982) |
| *Lyctus brunneus* | Old World lyctus beetle | | x | | | | | Gerberg (1957), ivie (2002), and Lewis and Seybold (2010) |
| *Lyctus linearis* | European powderpost beetle | x | x | | | | | Furniss and Carolin (1977), Gerberg (1957), and Ivie (2002) |
| *Mecinus janthinus* and *M. janthiniformis* | Toadflax stem-mining weevils | | x | x | | | x | Sing et al. (2016), Toševski et al. (2011), and Willden (2017) |
| *Micromalthus debilis*[b] | Telephone pole beetle | | | | | x | | Philips (2001) |
| *Monarthrum mali*[b] | Apple wood stainer | | x | | | | | Seybold et al. (2016) |
| *Nacerdes melanura* | Wharf borer | | x | | | | | Chamberlin (1953) |
| *Nathrius brevipennis* | A walnut twig borer | | x | | | | | Linsley (1963), Linsley and Chemsak (1997), and Seybold et al. (2016) |
| *Orchestes alni* | European elm flea weevil | x | | x | | x | x | Looney et al. (2012) and USDA (2019) |
| *Orthotomicus erosus* | Mediterranean pine engraver | x | x | | x | | | Lee et al. (2005) and Seybold et al. (2016) |
| *Otiorhynchus ovatus* | Strawberry root weevil | x | x | x | x | x | x | CABI (2018), Cranshaw et al. (1994), and USDA (2019) |
| *Otiorhynchus rugosostriatus* | Rough strawberry root weevil | x | x | x | x | x | x | CABI (2018) and Cranshaw et al. (1994) |
| *Otiorhynchus sulcatus* | Black vine weevil | x | x | x | x | x | x | CABI (2018), Cranshaw et al. (1994), and USDA (2019) |
| *Oulema melanopus* | Cereal leaf beetle | | x | | | | x | Dowell and Pickett (2016) |
| *Phloeotribus liminaris*[b] | Peach bark beetle | | x | | | | | Seybold et al. (2016) |
| *Phloeotribus scarabaeoides* | Olive bark beetle | | x | | | | | Arakelian (2017) and Atkinson (2018) |
| *Phloeosinus armatus* | Oriental cypress bark beetle | | x | | | | | Seybold et al. (2016) |
| *Phoracantha recurva* | Yellow *Phoracantha* | | x | | | | | Hanks et al. (1997), Paine (2016), and Paine et al. (2009) |
| *Phoracantha semipunctata* | Eucalyptus longhorned beetle | | x | | | | | Paine (2016), Paine et al. (2009), and Scriven et al. (1986) |
| *Pityophthorus juglandis*[b] | Walnut twig beetle | O | x | x | x | O | x | Seybold et al. (2016) |
| *Popilia japonica* | Japanese beetle | | x | x | | x | x | CABI (2018), Gaimari (2005), and USDA (2019) |
| *Rhinocyllus conicus* | Seedhead weevil | | x | x | x | x | x | Winston et al. (2014a) |
| *Rhinusa antirrhini* | Toadflax seed-galling weevil | | x | x | | | | Sing et al. (2016) |
| *Rhynchophorus ferrugineus* | Red palm weevil | | x | | | | | CFPC (2012) |
| *Rhynchophorus palmarum* | South American palm weevil | x | x | | | | | CFPC (2012) and Hodel et al. (2016) |

(continued)

**Table A4.3** (continued)

| Scientific name | Common name | Occurrence | | | | | | References |
|---|---|---|---|---|---|---|---|---|
| | | AZ | CA | CO | NV | NM | UT | |
| *Rhynchophorus vulneratus* | Asian palm weevil | | x | | | | | CFPC (2012) and Hoddle et al. (2017) |
| *Rodolia cardinalis* | Cottony cushion scale lady beetle = vedalia beetle | | x | | | x | | C. Sutherland, personal observation |
| *Scolytus multistriatus* | Smaller European elm bark beetle | x | x | x | x | x | x | Lee et al. (2009) and Seybold et al. (2016) |
| *Scolytus rugulosus* | Shot hole borer | x | x | x | x | x | x | Seybold et al. (2016) |
| *Scolytus schevyrewi* | Banded elm bark beetle | x | x | x | x | x | x | Lee et al. (2009) and Seybold et al. (2016) |
| *Sinoxylon ceratoniae* | | | x | | | | | Furniss and Carolin (1977) and Ivie (2002) |
| *Stegobium paniceum* | Drugstore beetle | x | x | x | x | x | x | CABI (2018), Phillips (2002), USDA (1986), and White (1982) |
| *Tenebroides mauritanicus* | Cadelle | x | x | x | x | x | x | Furniss and Carolin (1977) and USDA (1986) |
| *Trachymela sloanei* | Eucalyptus tortoise beetle | | x | | | | | Gill (1998) and Paine (2016) |
| *Trichosirocalus horridus* | A musk thistle biocontrol weevil | | | x | | x | | C. Sutherland, personal observation; Winston et al. (2014a) |
| *Trogoxylon aequale* | A powderpost beetle | x | | | | | | Gerberg (1957) (also occurs in Texas) |
| *Xanthogaleruca luteola* | Elm leaf beetle | x | x | x | x | x | x | CABI (2018), Cranshaw et al. (1994), and USDA (2019) |
| *Xestobium rufovillosum* | Deathwatch beetle | | x | | | | | Furniss and Carolin (1977) and Phillips (2002) |
| *Xyleborinus saxeseni* | Fruit-tree pinhole borer | x | x | x | x | x | x | Rabaglia et al. (2019) and Seybold et al. (2016) |
| *Xyleborus affinis*[b] | Oak-hickory ambrosia beetle | | x | | | | | Bright 2018; voucher specimen in the California Academy of Sciences, San Francisco |
| *Xyleborus dispar* | European shot hole borer | | x | | x | | x | Atkinson (2018), Linsley and MacLeod (1942), and Seybold et al. (2016) |
| *Xyleborus pfeili* | | | x | | | | | Seybold et al. (2016) |
| *Xyleborus xylographus*[b] | Oak timber beetle | | x | | | | x | Atkinson (2018) and Seybold et al. (2016) |
| *Xylosandrus germanus* | Black stem borer | | x | | | | | Rabaglia et al. (2019), Seybold et al. (2016), also occurs in Texas |
| **Diptera** | | | | | | | | |
| *Aedes aegypti* | Yellow fever mosquito | | x | | | | | CDPH (2019) |
| *Aedes albopictus* | Asian tiger mosquito | | x | | | | | CDPH (2019) |
| *Compsilura concinnata* | Gypsy moth parasitoid | | x | | | | | CABI (2018) and Sabrosky and Reardon (1976) |
| *Delia platura* | Seedcorn maggot | x | x | x | x | x | x | CABI (2018) |
| *Drosophila suzukii* | Spotted wing drosophila | | x | x | | | x | CABI (2018) |
| *Rhagoletis completa*[b] | Walnut husk fly | | x | x | x | x | x | Cranshaw et al. (1994), Foote and Blanc (1963), and Foote et al. (1993) |
| **Hemiptera** | | | | | | | | |
| *Acizzia uncatoides* | Acacia psyllid | | x | | | | | Paine (2016) |
| *Adelges piceae* | Balsam woolly adelgid | | x | | | | | CFPC (2012, 2013, 2017) and USDA (2019) |
| *Aonidiella aurantii* | California red scale | x | x | | | | | USDA (2019) |
| *Asterolecanium minus* | Oak pit scale | | x | | | | | Koehler and Tamaki (1964) and USDA (2019) |
| *Betulaphis brevipilosa* | A European birch aphid | | x | | | | | Hajek and Dahlsten (1986) |
| *Blastopsylla occidentalis* | A eucalyptus psyllid | | x | | | | | Paine (2016) |
| *Callipterinella calliptera* | A European birch aphid | | x | | | | | Hajek and Dahlsten (1986) |
| *Chionaspis etrusca* | Saltcedar armored scale | | | | | x | | C. Sutherland, personal observation |
| *Cryptoneossa triangular* | Lemon gum psyllid | | x | | | | | Paine (2016) |
| *Ctenarytaina longicauda* | A eucalyptus psyllid | | x | | | | | Paine (2016) |
| *Ctenarytaina spatulata* | A eucalyptus psyllid | | x | | | | | Paine (2016) |
| *Ctenarytaina eucalypti* | Blue gum psyllid | | x | | | | | Paine (2016) and USDA (2019) |
| *Diaphorina citri* | Asian citrus psyllid | x | x | | | | | Geiger and Woods (2009), Mead and Fasulo (2017), and Milosavljević et al. (2017) |
| *Diuraphis noxia* | Russian wheat aphid | | | | | x | | C. Sutherland, personal observation |

(continued)

**Table A4.3** (continued)

| Scientific name | Common name | Occurrence | | | | | | References |
|---|---|---|---|---|---|---|---|---|
| | | AZ | CA | CO | NV | NM | UT | |
| *Elatobium abietinum* | Spruce aphid | x | x | | x | x | x | Lynch (2004, 2014) and USDA (2019) |
| *Eucallipterus tiliae* | Linden aphid | | x | | | | | USDA (2019) |
| *Eucalytolyma maideni* | Spotted gum psyllid | | x | | | | | Paine (2016) |
| *Euceraphis betulae* | European birch aphid | | x | | | | | Hajek and Dahlsten (1986) |
| *Eulecanium cerasorum* | Calico scale | | x | | | | | USDA (2019) |
| *Glycaspis brimblecombei* | Red gum lerp psyllid | x | x | | | | | CFPC (2011), Fischer and Woods (2010), Paine (2016), and USDA (2019) |
| *Gossyparia spuria* | European elm scale | x | x | x | x | x | x | Cranshaw et al. (1994) and Miller and Miller (1993) |
| *Halyomorpha halys* | Brown marmorated stink bug | x | x | | x | x | x | CABI (2018) |
| *Homalodisca vitripennis* | Glassy-winged sharpshooter | | x | | | | | Paine (2016) |
| *Icerya purchasi* | Cottony cushion scale | x | x | | | x | | C. Sutherland, personal observation; USDA (2019) |
| *Lecanium (Parthenolecanium) corni* | European fruit lecanium | | x | | | x | x | CABI (2018) |
| *Lepidosaphes ulmi* | Oystershell scale | x | x | x | x | x | x | CABI (2018), Cranshaw et al. (1994), Miller and Davidson (2005), and USDA (2019) |
| *Maconellicoccus hirsutus* | Pink hibiscus mealybug | | x | | | | | USDA (2019) |
| *Melanaphis sacchari* | Sugarcane aphid | | | | | x | | C. Sutherland, personal observation |
| *Melanocallis caryaefoliae*[b] | Black pecan aphid | x | x | | | x | | C. Sutherland, personal observation |
| *Meliarhizophagus fraxinifolii* | Ash whitefly | | | | | x | | C. Sutherland, personal observation |
| *Metopoplax ditomoides* | | | x | | | | | Wheeler and Hoebeke (2012) |
| *Monellia caryella*[b] | Black-margined pecan aphid | x | x | | | x | | C. Sutherland, personal observation |
| *Monelliopsis pecanis*[b] | Yellow pecan aphid | x | x | | | x | | C. Sutherland, personal observation |
| *Nezara viridula* | | | x | | | | | CABI (2018) |
| *Opsius stactogalus* | Saltcedar leafhopper | | | | | x | | C. Sutherland, personal observation |
| *Parthenolecanium (= Lecanium) corni* | European fruit lecanium | | | x | | | | Cranshaw et al. (1994) |
| *Periphyllus lyropictus* | Norway maple aphid | | x | | | | x | USDA (2019) |
| *Periphyllus testudinacea* | Maple aphid | | x | x | | | x | Furniss and Carolin (1977) |
| *Phyllaphis fagi* | Beech woolly aphid | | x | | | | x | USDA (2019) |
| *Physokermes piceae* | Spruce bud scale | | x | | | | | USDA (2019) |
| *Pineus strobi* | Pine bark aphid | | | x | | | | Darr et al. (2018) |
| *Quadraspidiotus juglansregiae* | Walnut scale | | x | x | | | | Cranshaw et al. (1994) |
| *Quadraspidiotus perniciosus* | San Jose scale | | x | x | | | x | CABI (2018) and USDA (2019) |
| *Raglius alboacuminatus* | | | x | | | | x | Henry (2004) |
| *Shivaphis celti* | Hackberry woolly aphid | | x | | | | | Lawson and Dreistadt (2005) |
| *Sipha flava* | Yellow sugarcane aphid | | | | | x | | C. Sutherland, personal observation |
| *Sipha maydis* | Hedgehog aphid | | | | | x | | C. Sutherland, personal observation |
| *Siphoninus phillyreae* | Ash whitefly | | | | | x | | C. Sutherland, personal observation |
| **Thysanoptera** | | | | | | | | |
| *Taeniothrips inconsequens* | Pear thrips | | x | | | x | x | USDA (2019) |
| **Hymenoptera** | | | | | | | | |
| *Anaphes nitens* | An egg parasitoid of *G. scutellatus* | | x | | | | | Paine (2016) |
| *Aprostocetus* sp. | A gall-forming eulophid wasp | | x | | | | | Paine (2016) |
| *Avetianella longoi* | An egg parasitoid of *P. semipunctata* | | x | | | | | Paine (2016) |

(continued)

**Table A4.3** (continued)

| Scientific name | Common name | Occurrence | | | | | | References |
|---|---|---|---|---|---|---|---|---|
| | | AZ | CA | CO | NV | NM | UT | |
| *Caliroa cerasi* | Pear sawfly | | x | x | x | x | x | USDA (2019) |
| *Epichrysocharis burwelli* | A gall-forming eulophid wasp | | x | | | | | Paine (2016) |
| *Eupareophora parca* | | | x | | | | | Looney et al. (2016) |
| *Fenusa dohrnii* | European alder leafminer | | | x | | | | Cranshaw et al. (1994) |
| *Fenusa pusilla* | Birch leafminer | | | x | | | | Cranshaw et al. (1994) |
| *Fenusa ulmi* | Elm leafminer | | | x | | | | Cranshaw et al. (1994) and USDA (2019) |
| *Linepithema humile* | Argentine ant | | x | | x | | | Tsutsui et al. (2001) and Knight (2018) |
| *Nematus ribesii* | Imported currantworm | | | x | | | | Cranshaw et al. (1994) |
| *Ophelimus maskelli.* | A gall-forming eulophid wasp | | x | | | | | Paine (2016) |
| *Polistes dominula* | European paper wasp | | x | | | | | Pilowsky and Starks (2018) |
| *Pristiphora rufipes* | | | | x | | | | Cranshaw et al. (1994) |
| *Psix tunetanus* | Parasitoid of Pentatomidae | x | x | | | x | x | Johnson and Masner (1985) |
| *Psyllaephagus bliteus* | Parasitoid of *Glycaspis brimblecombei* | | x | | | | | Paine (2016) |
| *Psyllaephagus parvus* | Parasitoid of *Eucalytolyma maideni* | | x | | | | | Paine (2016) |
| *Psyllaephagus perplexus* | Parasitoid of *Cryptoneossa triangular* | | x | | | | | Paine (2016) |
| *Psyllaephagus pilosus* | Parasitoid of *Ctenerytina eucalypti* | | x | | | | | Paine (2016) |
| *Quadrastichodella nova* | Seed-galling eulophid wasp | | x | | | | | Paine (2016) |
| *Selitrichodes globulus* | A gall-forming eulophid wasp | | x | | | | | Paine (2016) |
| *Solenopsis invicta* | Red imported fire ant | | x | | | | | Greenberg and Kabashima (2013) |
| *Vespula germanica* | German yellowjacket | | x | | | | | Lester and Beggs (2019) |
| **Lepidoptera** | | | | | | | | |
| *Anarsia lineatella* | Peach twig borer | x | x | x | x | x | x | USDA (2019) |
| *Calophasia lunula* | Toadflax defoliating moth | x | | x | | | | Sing et al. (2016) |
| *Caloptilia negundella* | Boxelder leafroller | | | x | | | | Cranshaw et al. (1994) |
| *Caloptilia syringella* | Lilac leafminer | | | x | | | | Cranshaw et al. (1994) |
| *Epiphyas postvittana* | Light brown apple moth | | x | | | | | Bohne (2008), Brown (2007), CFPC (2012), and Geiger and Woods (2009) |
| *Homadaula anisocentra* | Mimosa webworm | | x | | | | | USDA (2019) |
| *Hyles euphorbiae* | Leafy spurge hawk-moth | | x | x | | | | Lotts and Naberhaus (2017) |
| *Leucoma salicis* | Satin moth | | x | | x | | | Phillips (2018) and USDA (2019) |
| *Leucoptera spartifoliella* | Scotch broom twig miner | | x | | | | | Andreas et al. (2017) and Winston et al. (2014b) |
| *Lymantria dispar dispar*[a] | North American gypsy moth | | x | | | | x | Bohne (2007, 2008) |
| *Lymantria dispar asiatica/japonica*[a] | Asian gypsy moth | | x | | | | | Bohne (2007, 2008) and Bohne and Rios (2006) |
| *Rhyacionia buoliana* | European pine shoot moth | | | | | | x | USDA (2019) |
| *Rhyacionia frustrana*[b] | Nantucket pine tip moth | | x | | | x | | Brown and Eads (1975) and Cranshaw (1984) |
| *Synanthedon scitula* | Eastern dogwood borer | | | x | | | | Cranshaw et al. (1994) |

[a]These species have been introduced repeatedly into the Southwest region, but do not have known established populations
[b]These species are native to other regions of North America, but have invaded the Southwest region (except for *A. auroguttatus, D. wrightii, I. calligraphus*, and *P. juglandis*, which are native originally to certain States in the Southwest region, but have spread to other States within the region. In these instances, the original States are marked with circles in the table)

cies were first detected in heavily urbanized southern California, which appears to be a particularly fertile area for their introduction and establishment due to the proximity of ship traffic and associated cargo, as well as the great diversity of potential hosts in the urban forest. The extra-continental invasive bark and ambrosia beetles in California comprise nearly 30% of the 58 documented invasive species of bark and ambrosia beetles in the United States (Haack 2001, 2006; Haack and Rabaglia 2013; Lee et al. 2007). Since invasive species often reassociate themselves with their hosts of origin (i.e., in this case adventive populations of trees) in the invaded habitat (Mattson et al. 1992; Niemelä and Mattson 1996), it is not surprising that some of the key invasive bark and ambrosia beetles in California are of Mediterranean origin (Mifsud and Knížek 2009). However, there is also a trend toward the introduction and establishment of Asian invasive species in California (e.g., polyphagous and Kuroshio shot hole borers (*Euwallacea* sp.) (Fig. A4.6) and banded elm bark beetle). The latter elm bark beetle has largely replaced the smaller European elm bark beetle (*S. multistriatus*) throughout the Southwest region (Lee et al. 2009). The banded elm bark beetle has also been shown to vector *Ophiostoma novo-ulmi*, the pathogenic agent of Dutch elm disease (Jacobi et al. 2007, 2013). However, unlike urban forests in the Eastern United States and Europe where susceptible elm species were planted frequently, urban forests in many southern cities in the Southwest region are characterized more by Chinese and Siberian elms (*U. parvifolia* and *U. pumila*, respectively) which have been less susceptible to Dutch elm disease (Strobel and Lanier 1981). Among the States of the region, the disease was recorded initially for some years in only California and Colorado (Barger and Hock 1971; Strobel and Lanier 1981). The advent of the banded elm bark beetle, which has a preference for Siberian elm, may change the dynamics of disease transmission to these Asian hosts in the future (Lee et al. 2010).

California has also been a hotbed of invasive species of insects that feed on eucalypts, where nearly 20 insects from 4 feeding guilds, largely derived from Australia, have become established (Paine 2016). The only introduced termite with established populations in the Southwest Region, the Formosan subterranean termite (*Coptotermes formosanus*), began its invasion in southern California as well (Rust et al. 1998). The powderpost termite (*Cryptotermes brevis*) has been detected in California in wood furnishings or structures on occasion, but there are no reports of any established populations in the Southwest region (Evans et al. 2013; Light 1936; Rust 2004; Scheffrahn et al. 2009). Finally, the major invasive ant in the region, the Argentine ant (*Linepithema humile*), was, at the outset, also uniquely established within the region in California (Tsutsui et al. 2001), but has since been detected in both Northern and Southern Nevada (Knight 2018).

Climate change is exerting a broad impact on the population biology of native bark beetles and potentially other subcortical insects in North America (Bentz et al. 2010), with the most obvious effects at higher elevations and latitudes. In the Southwest region, there also appears to be a trend, whereby southern populations of indigenous exotic subcortical species are invading and expanding their populations generally northward. Examples of this include the Mexican pine beetle (*Dendroctonus mexicanus*) (Moser et al. 2005), the Mexican soapberry borer (*Agrilus prionurus*) (Billings et al. 2014), the walnut twig beetle (*P. juglandis*) (Rugman-Jones et al. 2015), the goldspotted oak borer (*Agrilus auroguttatus*) (Coleman and Seybold 2016), and two other newly discovered flatheaded borers in California, *Chrysobothris analis* (Westcott et al. 2015) and *C. costifrons costifrons* (Basham et al. 2015). A variation on this theme has occurred with the South American palm weevil (*Rhynchophorus palmarum*), which was introduced into Tijuana, Baja California, Mexico, and then subsequently expanded its distribution northward into San Diego County, CA (Hodel et al. 2016). Whether or not this trend of "latitudinal creep" will continue to manifest itself in the urban, peri-urban, and wildland forests of the Southwest region remains to be seen.

There have been periodic introductions of two subspecies of gypsy moths (*Lymantria dispar*), in the Southwest region (see Chap. 2, Sect. 2.3; Chap. 7, Sect. 7.4.1; and the Northwest and Southeast and Caribbean regional summaries for additional discussion of this insect complex). Immatures (larvae) of European gypsy moth (*Lymantria d. dispar*), detected but eradicated from Utah, Colorado, and California, and Asian gypsy moth (*L. d. asiatica/japonica*), detected but eradicated from California (Bohne and Rios 2006; Fischer and Woods 2010), are major defoliators of valuable species of street and forest trees (Pogue and Schaefer 2007). Asian gypsy moth occurs in temperate Asia from the Ural Mountains east to China, Korea, and the Russian Far East (north of the Himalayas), whereas European gypsy moth, native originally to Europe, has been established in the eastern portion of the United States since the late 1860s (Liebhold et al. 1989). An extensive detection system is in place throughout most of the developed areas in the Southwest region providing an early detection resource (Bohne 2007; CFPC 2017). When introductions are detected, eradication strategies have been used to avoid population establishment in the Southwest region.

Most of the invasive insect taxa with the highest potential impact for forests of the Southwest region have also been first introduced into southern California. These established species include the goldspotted oak borer (Coleman and Seybold 2016), the polyphagous shot hole borer/Kuroshio shot hole borer complex (Chen et al. 2017; Fig. A4.6), the Mediterranean pine engraver (*Orthotomicus erosus*) (Lee et al. 2005, 2008), and the red-haired pine bark beetle (*Hylurgus ligniperda*) (Liu et al. 2007). An ensemble of massive *Rhynchophorus* weevils (Table A4.3) present a major


**Fig. A4.6** The polyphagous and Kuroshio shot hole borers (*Euwallacea whitfordiodendrus and E. kuroshio* (Coleoptera: Scolytidae)) are populations of invasive ambrosia beetles whose invaded ranges are centered in Los Angeles and San Diego Counties, CA, respectively [species nomenclature as per Gomez et al. (2018)]. They originate from Asia and threaten riparian hardwoods in southern California (Coleman et al. 2013). (**a**) Female (*upper*) and male (*lower*) polyphagous shot hole borers (PSHB); (Photo credit: Stacy Hishinuma, University of California, Davis). (**b**) Egg galleries created by female PSHB in the xylem of castor bean (*Ricinus communis* L.), which is itself an invasive plant in southern California. Note the dark staining from symbiotic fungi such as *Fusarium euwallaceae* (Eskalen et al. 2013; Lynch et al. 2016) (Photo credit: Tom W. Coleman, USDA Forest Service, Forest Health Protection, Albuquerque, NM). (**c**) Density of sap stain spots on the bark surface of California sycamore (*Platanus racemosa*) indicates the extent of aggregation as female PSHB colonize the xylem on the main stem of this host. The xylem of exposed roots and branches can also be colonized (Photo credit: T.W. Coleman). (**d**) Landscape-level impact of Kuroshio shot hole borer in the Tijuana River Valley Regional Park, San Diego County, CA. In this river delta, damage is primarily to arroyo and red willow (*Salix* spp.) and castor bean. *Inset* shows bark surface of willow with "toothpick-like" strands of boring dust (frass) expelled from entrance holes by female PSHB. (Photo credit: John Boland, unaffiliated research scientist, and (*inset*) Adrian Poloni, University of California, Davis)

threat to urban Canary Island date palms (*Phoenix canariensis*) and related palms that provide shade and ornament to the urban forests of southern California, Las Vegas, and Phoenix (Hoddle et al. 2017; Hodel et al. 2016). Small introduced populations of the Asian longhorned beetle (*Anoplophora glabripennis*), a woodboring pest of maples (*Acer* spp.) and other hardwoods, have been eradicated from California (Bohne 2007, 2008; Bohne and Rios 2006), but, if established, this pest also presents a high risk to the Southwest region. An example of an invasive species with great potential for urban and riparian forest impact in the Southwest region that has not yet reached California is the emerald ash borer (*Agrilus planipennis*), which has recently established populations in Colorado (Colorado State Forest Service 2018) (see Chap. 2, Box 2.5 and Chap. 7).

Three invasive insect species that bridge agro- and forest ecosystems of the Southwest region are the aforementioned walnut twig beetle, the pecan weevil (*Curculio caryae*), and the light brown apple moth (LBAM) (*Epiphyas postvittana*). The walnut twig beetle and the pecan weevil are both native invasive species with the walnut twig beetle originating from Arizona and New Mexico (Rugman-Jones et al. 2015), whereas the weevil has coevolved with native stands of hickory (*Carya*) species in the Eastern United States (Mulder et al. 2012). The walnut twig beetle has invaded the entire Southwest region; so far, the weevil is only found in New Mexico (Sutherland et al. 2017). The walnut twig beetle cannot develop in pecan (*Carya illinoensis*) (Hefty et al. 2018), but both species may utilize English walnut (*Juglans regia*) as hosts (Hefty et al. 2018; Mulder et al. 2012). Thus, as a duo, the two invaders threaten pecan and walnut nut production in the Southwest region. A complex of aphids from the Eastern United States (Table A4.3) also cause damage to pecan trees in orchards in AZ, CA, and NM. Light brown apple moth, native to Australia, was first found in the San Francisco Bay Area in 2006 (Brown 2007) and has since been detected in 15 coastal and near coastal counties in California (Gutierrez et al. 2010). It is highly polyphagous, but considered primarily as a pest of pome fruits (Rosaceae) and grapes (*Vitis* spp.). For several years, it was regarded as a potential invasive pest of numerous forest and shade trees, but to date has not been recorded causing substantial damage to trees in California (Bohne 2008; CFPC 2012; Geiger and Woods 2009). Using a temperature-driven demographic model and climatic data from 151 locations in California, Gutierrez et al. (2010) predicted that near-coastal regions of California are most favorable for light brown apple moth, northern Central Valley areas were less favorable, and desert regions of Arizona and California are unfavorable.

### Vertebrates

A modest number of invasive vertebrates are worth noting in the Southwest region (Table A4.4). A number of ungulate species introduced into the Southwest region have become problematic. Among these are exotic species such as Barbary sheep (*Ammotragus lervia*) and African oryx (*Oryx gazelle*) which were brought over originally from Africa as game animals. The Barbary sheep threatens desert bighorn sheep (*Ovis canadensis Mexicana*), in its native habitat (Novack et al. 2009), whereas expanding oryx populations can damage soil and vegetation resources (Conrod 2004). Of particular concern are invasive feral swine (*Sus*

**Table A4.4** The primary invasive vertebrates of the Southwest region include amphibians, fish, mammals, and reptiles

| | | Occurrence | | | | | | References |
|---|---|---|---|---|---|---|---|---|
| Scientific name | Common name | AZ | CA | CO | NV | NM | UT | |
| *Lithobates catesbeianus (Rana catesbeiana)* | American bullfrog | x | x | x | x | x | x | Lever (2003) |
| *Hypophthalmichthys* spp. *Ctenopharyngodon* spp., *Mylopharyngodon piceus* | Carp (Asian, black, big head, diploid grass, silver) | x | x | x | x | x | x | NAS (2019) |
| *Salmo salar* | Atlantic salmon | | x | x | x | | x | NAS (2019) |
| *Didemnum vexillum* | Carpet sea squirt | x | | | | | | CABI (2018) |
| *Chelydra serpentina serpentina* | Eastern snapping turtle | | x | | | | | Fuller et al. (2018b) |
| *Neogobius melanostomus, Rhinogobius brunneus, Tridentiger bifasciatus Acanthogobius flavimanus* | Goby | | x | | | | | Nico et al. (2018b) |
| *Notemigonus crysoleucas* | Golden shiner | x | x | x | x | x | x | Nico (2018) |
| *Esox* spp. | Muskellunge/northern pike | x | x | x | x | x | x | Fuller and Neilson (2018b) |
| *Trachemys scripta elegans* | Red-eared slider | x | x | | | x | | Somma et al. (2019) |
| *Scardinius erythrophthalmus* | Rudd | | | x | | | | Nico et al. (2018a) |
| *Channa argus* | Northern snakehead | | x | | | | | Fuller et al. (2018a) |
| *Dorosoma petenense* | Threadfin shad (yellowtails) | x | x | x | x | x | x | Fuller and Neilson (2018a) |
| *Clarias* spp. | Walking catfish | | x | | x | | | Nico et al. (2018c) |
| **Terrestrial vertebrates** | | | | | | | | |
| *Ammotragus lervia* | Barbary sheep | x | x | x | | x | | CABI (2019) |
| *Cygnus olor* | Mute swan | | x | | | | | CABI (2018) |
| *Myocastor coypus* | Nutria | | x | x | | x | x | CABI (2018) |
| *Oryx gazella* | African oryx | | | | | x | | Morrison (1981) |
| *Sus scrofa* | Feral swine | x | x | x | x | x | x | McClure et al. (2018) |

*scrofa*), which include free-roaming European wild boars, former domestic pigs, and hybrids (see Chap. 2, Sect. 2.4 and the Southeast and Caribbean regional summary for additional discussion of this invasive vertebrate). Feral swine rooting in the litter layer and soil for food can cause soil erosion, property damage, destruction of ground nests of birds, and establishment of invasive plants. Feral swine may also transmit diseases to domestic livestock and indirectly to humans by facilitating the spread of ticks and tick-borne pathogens (see Chap. 2, Sect. 2.4) (Sanders et al. 2013). They have been particularly damaging to agricultural properties in California (White et al. 2018). APHIS is currently engaged in limiting westward expansion of feral swine by eradicating local feral swine populations in New Mexico and San Diego County, California. However, feral swine may be protected by local property owners who are interested in maintaining them for hunting. The nutria (*Myocastor coypus*), a large South American rodent, was discovered in California in March 2017 and is now found in five counties to the southeast of the Sacramento-San Joaquin Delta (Sabalow 2018). They feed on native wetland vegetation and burrow into levees and ditch banks, which poses a threat to water management in this vital region. Howard (1953) described an earlier introduction of nutria to Stanislaus County, California (1942–1952), from escapees from several fur farming operations based on animals imported from New Jersey and Louisiana. Howard's description underscores the inherent difficulties associated with eradicating this highly fecund invader. California's Central Valley and parts of Southern Nevada and Western Arizona have been modeled as suitable habitat for nutria (Jarnevich et al. 2017).

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