6.0 INVASIVE ANIMALS

6.1 OVERVIEW

Invasive animals refer to aquatic and terrestrial animal species, including pests, that are not native to the area and that tend to spread to a degree that causes damage to MSP species and/or the habitats they depend on. Invasive animals "threaten the diversity or abundance of native species through competition for resources, predation, parasitism, interbreeding with native populations, transmitting disease or causing physical or chemical changes to the invaded habitat" (CDFW 2016).

The species composition of natural communities in the San Diego region has undergone significant changes since the area was first settled. Many invasive animals have entered the area through accidental introduction via commercial shipping, small fishing boats, and commercial watercraft (CDFW 2016). Other means of unintentional spread occur when people travel between natural areas, farms, or waterways, carrying the exotic species on their vehicles, boats, equipment, or clothing. Additionally, there have been intentional introduction of animals brought in as sources of food, fur, or pets.

Prevention is the best strategy for managing invasive animal species. While not all nonnative species will survive introduction into a new system, nonnative species that are particularly invasive will be able to establish and become difficult to remove. Once an invasive animal species has been introduced to an area, early detection and rapid response are the best ways to stop the spread of an invasion. The longer an infestation is allowed to progress, the more extensive the damage and costs for control, and the less efficient the control efforts CDFW 2016).

To avoid costly treatments aimed at species eradication, it is imperative to focus efforts on prevention efforts. At least, prevention efforts should include increased education/public information, coordination, and cooperation. Additionally, prevention efforts often require exclusionary policies or apparatuses (technologies, facilities, and personnel) (McNeely et al. 2001; National Invasive Species Council 2001; Wittenberg and Cock 2001). Screening systems, codes of conduct, preclearance, and compliance agreements are also means of biosecurity (Meyerson and Reaser 2002).

6.1.1 Biosecurity

Biosecurity measures are the best way to strengthen and promote prevention efforts. In an ecological context, biosecurity refers to preventative measures intended to reduce the risk of nonnative and invasive species (plant, mammal, invertebrate, etc.) introduction and spread. The costs of nonnative species invasions and the costs to control those species often outweigh the financial costs of limiting or preventing the invasion in the first place. Biosecurity is a means of controlling invasions and may include surveillance programs and networks, identification of specimen to the species level, mandatory restrictions, and more. Biosecurity includes prevention, early detection, and rapid response.

6.1.2 Early Detection Rapid Response

Once a species is beyond prevention measures, time becomes the most important predictor for the significance of its effect (Meyerson and Reaser 2002). Early detection is imperative for reducing the costs for controlling the species and increasing the possibility for eradication. Effective early eradication systems consist of inventory and monitoring programs conducted by knowledgeable surveyors (National Invasive Species Council 2001; Wittenberg and Cock 2001). The ability to accurately identify any intercepted specimen to the species level is essential for early detection system (Armstrong and Ball 2005). High priority should be given to pathways and sites of potential invasion that are of particularly high risk (Meyerson and Reaser 2002).

Once an invasive animal is detected, mechanisms must be in place for a quick response for eradication, control, or containment. Meyerson and Reaser recommend developing a rapid response program, in close cooperation with state and local efforts, to immediately respond to the invasive animal detection. This program would require governments and other bodies to establish emergency action funding, establish or modify policies to support rapid response, and develop and improve techniques to eradicate and control invasives (Meyerson and Reaser 2002).

The key elements of any response include positive identification of the suspect exotic animal; identification of the incursion pathway; establishing the extent of the spread; eradication, containment, or other management actions; consultation; and communications (Pascoe 2002).

6.2 EFFECTS OF INVASIVE ANIMALS ON SOUTHERN CALIFORNIA ECOSYSTEMS

Invasive animals can impact the native species and habitat in a single way or many ways, sometimes directly and sometimes indirectly. A few of those impacts are summarized below.

6.2.1 Agriculture

Invasive pests that destroy native plants can also have large impacts on agricultural plants. The shot hole borer (*Euwallacea* sp. *#1 and Euwallacea* sp. #5) is such a pest and poses a severe threat to the agricultural industry. It uses avocado trees as its reproductive host and has been known to attack 12 other agriculturally important crops (Eskalen et al. 2013). Shot hole borer infestations cause *Fusarium* dieback in infected avocado trees, causing branch dieback and sometimes death of the tree. See further discussion below on impacts of shot-hole borer and *Fusarium* dieback to native vegetation.

6.2.2 Competition for Resources

Competition for resources from invasive animals can have detrimental impacts to native animal species. For example, European starlings (*Sturnus vulgaris*) compete with cavity-nesting birds for nesting sites. Brown-headed cowbirds (*Molothrus ater*) also compete with native birds through nest parasitism, leading to native birds unknowingly rearing brown-headed cowbird chicks instead of their own (Leatherman BioConsulting Inc. 2012). Invasive red-eared sliders (*Trachemys scripta elegans*) will outcompete the native southwestern pond turtle for food, egg-laying sites, and basking sites (Brown et al. 2015).

6.2.3 Disease

Invasive animals can spread bacterial, protozoal, and viral pathogens directly to native species through contact, or indirectly through fleas and other vectors. Cats (*Felis catus*), parrots (various spp.), and opossums (*Didelphis virginiana*) are a few of the nonnative animals in San Diego that could pose disease threats to the native species (Fisher, pers. comm., 2016).

6.2.4 Food Webs

Invasive animals can disrupt food webs in natural areas directly through predation, or indirectly through the consumption of prey species, increasing competition for the native species. Invasive animals can also alter food webs through the disruption of native pollinators and other arthropods. An example of this is the Argentine ant (*Linepithema humile*), which displaces native arthropods that are an important food source for several bird species, the Blainville's horned lizard, and others (Holway and Suarez 2006).

6.2.5 Genetics

While hybridization is less of a concern with animals than with plants, it can still occur in rare cases and present problems for native species genetics. The Sonoran spotted whiptail (*Aspidoscelis sonorae*) is an example of an invasive animal presenting such a problem. This lizard is native to southeastern Arizona, but has recently been found in Orange County. As a parthenogenic species, if this species were to reach San Diego, it is possible for it to hybridize with the native whiptails (Fisher, pers. comm., 2016).

6.2.6 Habitat

In addition to direct impacts on native species, invasive animals can also degrade and reduce the habitat available to native species. For example, rooting by feral pigs (*Sus scrofa*), overturns surface vegetation and below ground plant tissue (Sweitzer and Van Vuren 2008). Additionally, rooting in riparian zones disturbs sensitive vegetation and increases the risk of invasive plant spread.

6.2.7 Reproduction

Invasive animals can hinder reproduction of native species through consumption of their eggs and larvae. For example, the egg masses of the California newt (*Taricha torosa*), are consumed by the invasive swamp crayfish (*Procambarus clarkia*) (Kats et al. 2013). The egg masses contain a neurotoxin that deters most native species; however, the nonnative swamp crayfish are not deterred. Many streams with crayfish have experienced declines or complete elimination of California newts. Argentine ants can also impact the reproduction of San Diego barrel cactus (*Ferocactus viridescens*) by displacing native ants and deterring pollinators, resulting in reduced seed production by the barrel cactus (LeVan et al. 2014).

6.3 INVASIVE ANIMALS IN THE MSPA

Numerous nonnative aquatic and terrestrial animal species are present in the MSPA. While not all are invasive, there are many alien species that qualify as invasive due to their ability to persist in the region and cause harm to the native flora and fauna.

6.3.1 Invasive Aquatic Animal Species

Numerous exotic aquatic species have been introduced into southern California streams, ponds, and rivers. These invasive aquatic animals include red-eared sliders, largemouth bass (*Micropterus salmoides*), brown trout (*Salmo trutta*), black bullhead (*Ameiurus melas*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), mosquitofish (*Gambusia affinis*), African clawed frog (*Xenopus laevis*), American bullfrog (*Rana catesbeiana*), crayfish (*Procambatus clarkia*), and tiger salamander (*Ambystoma tigrinum*). These exotic species prey upon and/or compete for food with MSP species such as southwestern pond turtle and arroyo toad as well as other native amphibians and fish (Madden-Smith et al. 2005).

Historically, most southern California streams and rivers were ephemeral, drying up during the summer drought. However, increasing urbanization in the region has caused many streams and rivers to become perennial or for pools to persist as a result of water transfers between reservoirs, storm event urban runoff, and aseasonal flows from developed areas. This allows establishment and persistence of exotic aquatic species that could not persist when streams and rivers were dry during much of the year (Miller et al. 2012). When more than 8% of a watershed is developed, native amphibian species populations decline (Riley et al. 2005; Miller et al. 2012).

6.3.2 Invasive Terrestrial Animal Species

The terrestrial invasive species of concern include Argentine ants, brown-headed cowbirds, feral pigs, feral cats, the goldspotted oak borer (*Agrilus auroguttatus*), shot-hole borers, and more. A few of these species are described in more detail below.

<u>Argentine Ants</u>

Argentine ant populations are present throughout urban areas in San Diego County. Argentine ants tend to replace native ants by outcompeting them for resources (Suarez, Bolger, and Case 1998; Holway and Suarez 2006). They can also alter the composition and abundance of native arthropod communities; prey upon dependent baby birds and mammals; and eliminate native ant resources for the horned lizard, ground-foraging birds, and other species. Cactus bees spent less time in flowers of San Diego barrel cactus (*Ferocactus viridescens*) that were occupied by the Argentine ant compared to those occupied by the native *Crematogaster californica.* This decrease in the duration of visits is likely the cause for the decrease in seed set per fruit by cacti occupied by Argentine ants, and likely the cause of the production of fewer seeds overall.

Conserved Lands bordering urban areas and riparian corridors are at greatest risk of Argentine ant infestation. Conserved Lands less than 250 meters from an urban or agricultural edge may have significantly higher populations of Argentine ants and reduced native arthropod diversity and abundance, including fewer native ant species (Bolger 2007; Mitrovich et al. 2010). In narrow preserves, little to no portion of the preserve may be more than 250 meters from the urban edge (Figure V2B.6-1), such as the predominate situation found in MU2 where 93% of Conserved Lands are in urban edge (Table V2B.6-1).

Native ants tend to adapt to drought conditions more easily than Argentine ants and extended droughts can eliminate Argentine ants from some areas. Moist/wet conditions, created by urban drool, green waste dumping, irrigation along the edge and within preserves, and mulching within and adjacent to preserves can all contribute to Argentine ant invasion and occupancy of Conserved Lands (Mitrovich et al. 2010). In San Diego County, Argentine ant numbers fluctuate annually, most likely due to rainfall patterns. Global climate change may pose a unique threat to native ants and other invertebrates by changing rainfall patterns and increasing the distance from edge of preserves that Argentine ants occupy (Bolger 2007).

Brown-headed Cowbird

Brown-headed cowbirds are native to the Great Plains where they historically followed herds of grazing bison. However, in the late 1800s, brown-headed cowbirds expanded their range into California (Unitt 1984) due to landscape conversions. They were first recorded in San Diego County in 1862 near Cuyamaca Peak. The first incidence of breeding was reported in 1911 in National City, with eggs found in the nests of the least Bell's vireo. Cowbirds are now widely distributed and abundant as breeding summer residents throughout San Diego County and as localized winter visitors.

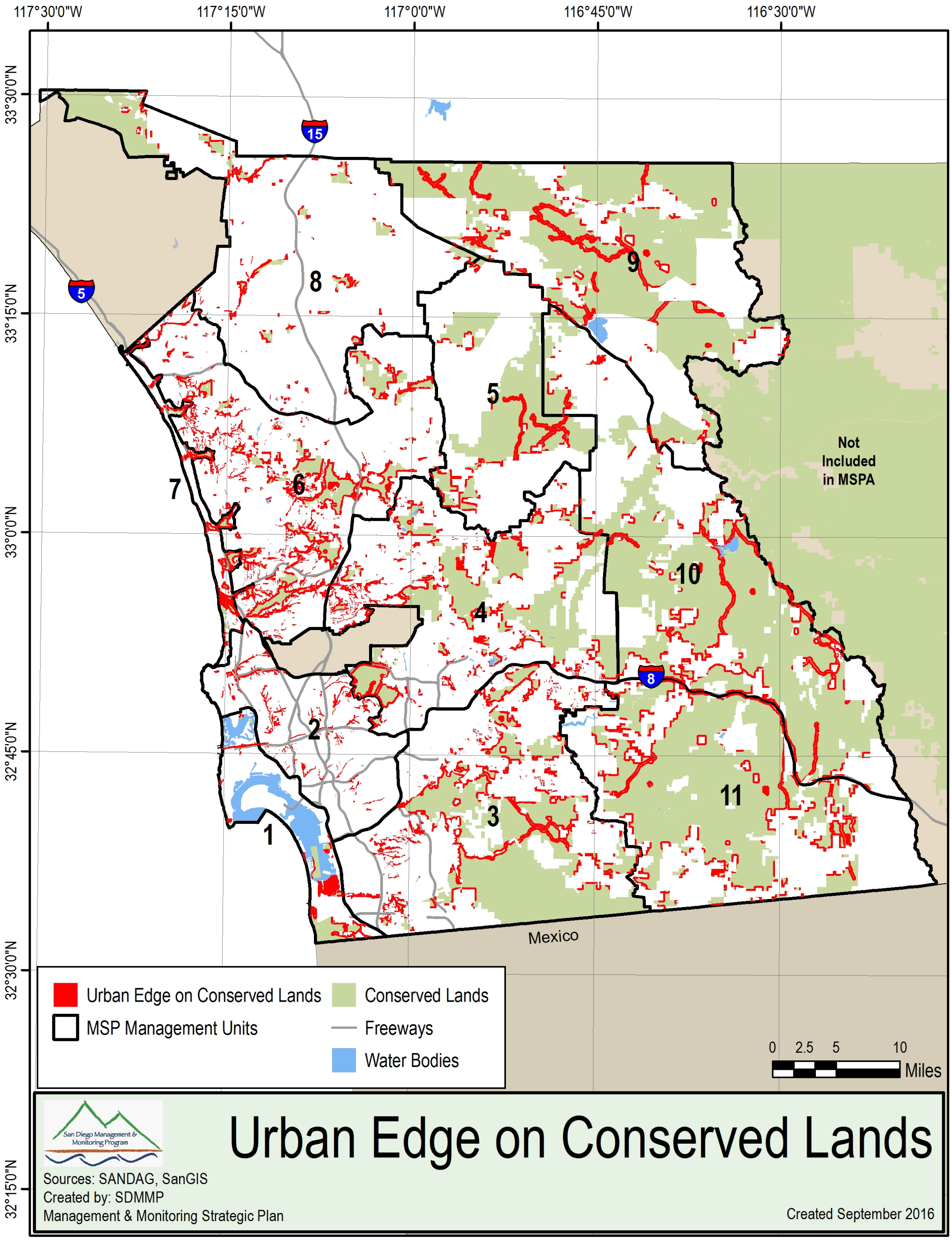

Figure V2B.6-1. Conserved Lands within 250 meters of an urban edge that are at risk of invasion by Argentine Ants.

Table V2B.6-1. Percent of area of Conserved Lands with urban edge.

MU	Acres of Conserved Land in Urban Edge	Total Acres of Conserved Land	Percent of Conserved Land in Urban Edge
1	3,742.4	7,245.6	51.7
2	5,520.7	6,736.2	82.0
3	20,388.5	85,122.9	24.0
4	17,484.5	58,467.2	29.9
5	6,612.5	40,129.2	16.5
6	27,630.5	42,946.3	64.3
7	3,029.5	3,817.8	79.4
8	5,964.3	23,881.6	25.0
9	17,571.1	137,926.2	12.7
10	18,759.7	141,868.2	13.2
11	17,262.3	115,258.8	15.0

Brown-headed cowbirds are obligate brood parasites that lay their eggs in the nests of other bird species, often destroying or expelling the eggs and young of the host species. The cowbirds rely on the host species to incubate their eggs and raise their young (Leatherman BioConsulting Inc. 2012). As a result of this parasitism, noticeable declines in passerine birds have been observed since the 1940s (Grinnell and Miller 1944). Cowbirds are extreme generalists and are known to parasitize over 200 North American bird species (Friedmann and Kiff 1985, cited in Uyehara et al. 2000). Female cowbirds arrive at their breeding sites between mid-April to early-May (Fleischer et al. 1987; Braden et al. 1997), with most females laying eggs in May and June (Uyehara et al. 2000).

While some species from the Great Plains develop behavioral adaptations to deal with the parasitism, most southern California bird species do not recognize the cowbird eggs and will readily accept the egg as their own (Leatherman BioConsulting Inc. 2012). In a parasitized nest, cowbird young often hatch earlier and develop faster than the host young (Rothstein 2004). Cowbird young then outcompete the host nestlings, leading to substantially reduced reproductive success for the host species. Cowbird parasitism presents an additional threat to the federally endangered southwestern willow flycatcher and least Bell's vireo as well as the federally threatened coastal California gnatcatcher (*Polioptila californica californica*); these are species that are already experiencing extreme habitat loss and degradation (Rothstein 2004; California Department of Parks and Recreation [CDPR] 2007).

Brown-headed cowbirds frequently parasitize least Bell's vireos and southwestern willow flycatcher nests (Kus and Whitfield 2005; Sharp and Kus 2006) and have contributed to the decline of these 2 federally-listed species. Vireo nests that occur in high-density understory vegetation are less likely to be parasitized. Cowbird control has been a major focus of management of these 2 species in southern California. Over the past 20 years, trapping and removal of cowbirds has increased productivity of least Bell's vireos, resulting in an 8-fold population increase (Kus and Whitfield 2005). However, flycatchers have not increased in the same manner and may be more affected by other aspects of habitat quality and other unknown factors.

Cowbird trapping and nest monitoring during the nesting season has been an effective short-term, local control strategy for the recovery of vireo populations (McGraw 2006). However, trapping and nest monitoring has not reduced overall cowbird populations and should not be used as a long-term recovery strategy. Additionally, open-ended control of cowbirds may remove the selective pressures that allow the native species to evolve nest parasitism defenses (Kus and Whitfield 2005). These defenses have been observed in least Bell's vireo, a species that has been in contact with the cowbirds for a longer period of time (Parker 1999).

While cowbird removal has been effective at increasing vireo populations, it shifts the emphasis from managing other threats and leads to a long-term dependence on intensive management. If cowbird control is to be effective long term, suitable habitat must exist. An evaluation of alternative management approaches, including the protection and restoration of habitat, as well as the maintenance of natural processes, should be considered. USGS is currently evaluating brown-headed cowbird trapping programs to develop a trapping strategy that addresses recruitment and natural selection, and is cost effective to implement.

Feral Pigs

The first feral pigs in San Diego County were observed in 2006 (SANDAG 2014) and have the potential to severely impact many MSP species. Feral pigs spread rapidly throughout the eastern portion of the county, with the large pig concentrations in the Upper San Diego River area and its tributaries, lands on Palomar Mountain, and lands adjacent to Lake Henshaw (Figure V2B.6-2). Feral pigs threaten San Diego's native ecosystem due to their omnivorous diets and rooting behavior

(California Department of Parks and Recreation 2013). As opportunistic omnivores, pigs primarily eat plants "(roots, tubers, fruit, acorns, etc.), but they will also eat worms, insects, small mammals, eggs, and young of ground-nesting birds and reptiles" (California Department of Parks and Recreation 2013). MSP species particularly susceptible to pig damage include species at high risk of extirpation from the MSPA (e.g., southwestern pond turtle, willowy monardella, and arroyo toad).

Rooting overturns surface vegetation and plant tissue below the ground, exposing the soils to warming, drying, and erosion (Sweitzer and Van Vuren 2008). The soil nutrient process is also affected by rooting due to "the combined effects of aeration, mixing of different soil layers, and increased water infiltration that may leach some nutrients" (Lacki and Lancia 1986; Cushman et al. 2004). Rooting activity also damages seedlings, which is especially problematic for the regeneration of oak woodlands (Sweitzer and Van Vuren 2008). In San Diego, feral pigs root in riparian zones, disturbing sensitive vegetation and increasing the risk of invasive plant spread. Physical destruction of nests and eggs, and the destruction of water quality due to turbidity and bacterial contamination are added concerns (California Department of Parks and Recreation 2013). Apart from the degradation of San Diego's natural habitats, feral pigs also damage agricultural crops and private property. Additionally, there are food safety concerns and the potential for disease outbreak (Kreith 2007).

The San Diego County feral pig population appears isolated from populations in other counties and Baja California, Mexico, making it possible to eradicate the San Diego County population (SANDAG 2014). In 2012, USFS and BLM completed a Wildlife & Botany Biological Evaluation and Assessment for their feral pig management program on the Cleveland National Forest, BLM Lands and Capitan Grande Indian Reservation (Wells 2012). The management areas for the program covered San Diego, Orange, and Northern Riverside Counties and included 423,472 acres of National Forest lands, 179,694 acres of BLM lands, and 15,540 acres of tribal lands. This management program, consisting of census, monitoring, and removal programs, was intended to expand on existing efforts.

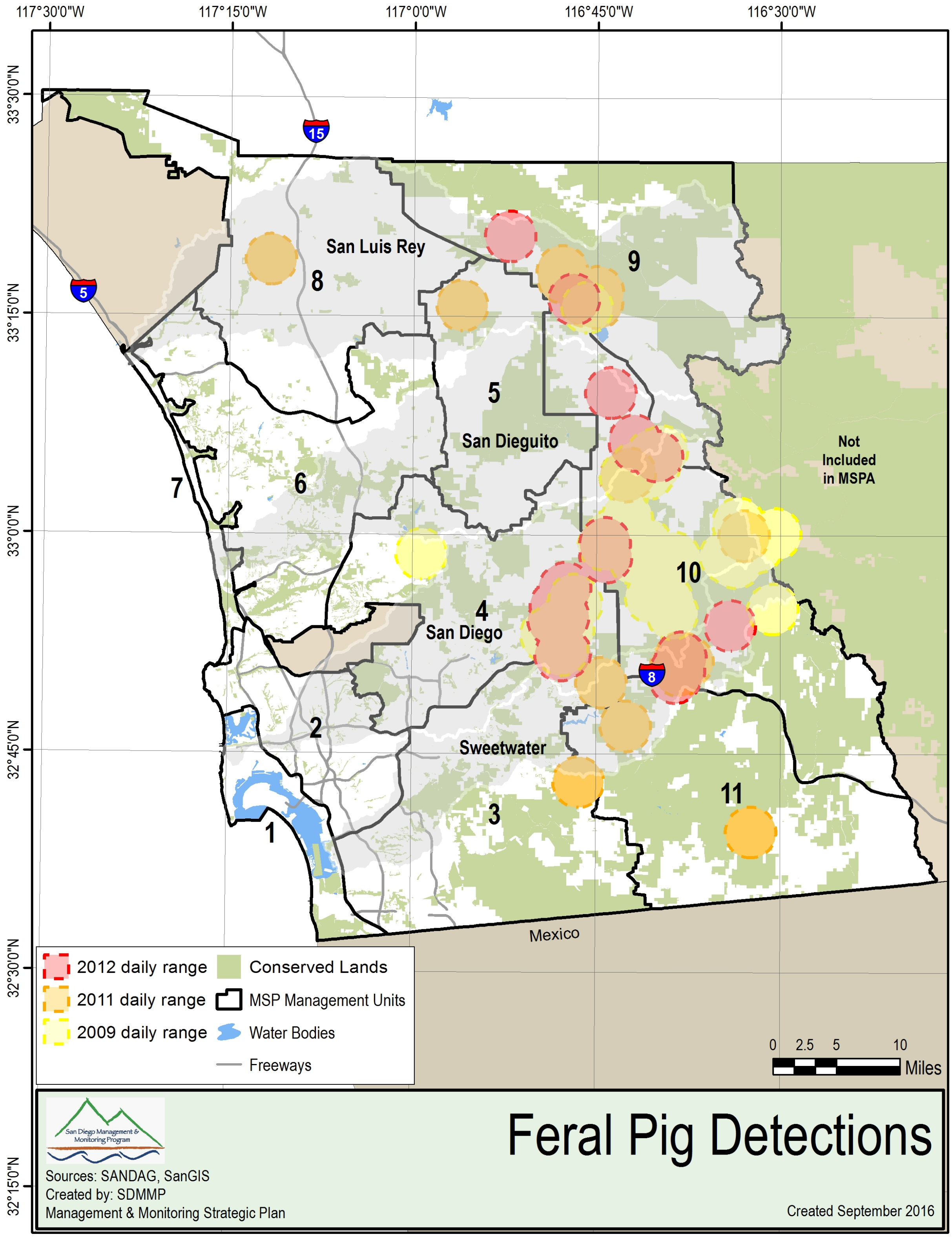

Figure V2B.6-2. Expansion of feral pigs into MSP lands since 2009.

In 2013, the State of California Department of Parks and Recreation completed the Draft Initial Study and Mitigated Negative Declaration Feral Pig Eradication and Control Project for the County of San Diego, with CDFW, City of San Diego, County of San Diego, Vista Irrigation District, and Helix Water District as responsible agencies (CDPR 2013). The primary elements of this project included inventory of pig populations, removal of feral pigs, and monitoring.

A 2014 eradication project by SANDAG and APHIS leveraged federal, state, and regional funding to maximize efficiency and cost sharing (SANDAG 2014). This 2-year project funded APHIS Wildlife Services staff members to monitor and eliminate feral pigs and feral pig sounders. After completion of this project in June 2016, the focus has switched to continued monitoring.

Feral Cats

Globally, domestic free-ranging cats are 1 of the 100 worst invasive animal species (Lowe et al. 2000) and have contributed to multiple wildlife extinctions on islands (Loss et al. 2013). A study by Loss et al. estimates that free-ranging cats kill 1.3–4.0 billion birds and 6.3–22.3 billion mammals annually in the United States These kills are primarily from feral cats rather than free-ranging pet cats. While the prey species preference appears to depend on the landscape type, on average, 33% of the birds killed were nonnative species. This amount of bird mortality from cats is greater than any other mortality source, such as collisions with windows, buildings, communication towers, and vehicles and pesticide poisoning. There are minimal studies on cat predation on reptiles and amphibians, but Loss et al. estimate the loss to be about 228–871 million reptiles and 86–320 million amphibians.

Fragmented habitat in California may be at a greater risk from feral cats, as increased predation is likely to occur in fragments <1.4 square kilometers where there is a higher density of cats (Soule et al. 1988; Crooks 2002). Circumstantial and anecdotal evidence suggests that domestic cats, along with gray foxes, are major contributors in the disappearance of wildlife from canyons (Soule et al. 1988). Cats are particularly detrimental as they will continue to kill wildlife in canyons long after the prey density is too low to sustain native predators; this is often due to their subsidized diet provided by humans.

From a study in an urban Michigan watershed, Ram et al. (2007) explained that cats and dogs contribute to more fecal coliform bacteria contamination than other sources, with cats twice as likely to be the source. From their findings, they emphasize the need for source tracking of cat fecal contamination of stormwater.

In addition to degrading water quality of water bodies on land, fecal coliform bacteria from cats can harm sea mammals, including Pacific harbor seals (*Phoca vitulina richardsi*) and California sea lions (*Zalophus californianus*) (Conrad et al. 2005).

While coyotes help to control the cat populations in canyons (Soule et al. 1988), more control is necessary. Models indicate that 71–94% of a feral cat population must be neutered, and there must not be any immigration, for the population to decline (Andersen et al. 2004; Foley et al. 2005).

<u>Goldspotted Oak Borer</u>

The goldspotted oak borer is a flat-headed borer that was introduced to California via infested firewood from Arizona (Lynch et al. 2013). It was first identified in California in 2004, but extensive oak mortality was not reported until 2008 (Hishinuma et al. 2011). By 2010, an estimated 21,500 trees had been killed, covering 1,893 square miles of San Diego County forests, parks, and residential landscapes (Hishinuma et al. 2011).

Goldspotted oak borer larvae feed under the bark of certain oaks near the phloem and xylem interface, which is the tissue where nutrients and water are conducted. The larvae damage both of these tissue layers, as well as the cambium, a unicellular layer responsible for radial growth (Hishinuma et al. 2011). Infested trees die after several years of injury inflicted by multiple generations of goldspotted oak borer. Trees that are predisposed by other injury, such as drought and root disease, succumb more quickly to the goldspotted oak borer effects (Coleman et al. 2015). In southern California, goldspotted oak borer is known to injure and kill coast live oak (*Quercus agrifolia*); California black oak (*Q. kelloggii*); canyon live oak (*Q. Chrysolepis*); and, in extremely rare cases, Engelmann oak (*Q. engelmannii*) (Hishinuma et al. 2011).

<u>Polyphagus/Kuroshio Shot Hole Borer</u>

Polyphagous shot hole borer, ***Euwallacea sp. #1***, and Kuroshio shot hole borer, ***Euwallacea*** sp. #5, collectively referred to as shot hole borers, are vectors for the invasive plant disease, *Fusarium* dieback. These shot hole borers are invasive ambrosia beetles known to severely damage tree species in riparian communities and urban areas through their symbiosis with *Fusarium* sp. (SANDAG 2016 *draft*). The beetles also pose a severe threat to the agricultural industry where they use avocado trees as a reproductive host. The polyphagous shot hole borer has been known to attack 12 other agriculturally important crops (Eskalen et al. 2013).

Polyphagous shot hole borer was first reported in southern California in 2003 and misidentified as the tea shot hole borer (Eskalen et al. 2012). The first Kuroshio shot hole borer was discovered in San Diego in 2014 (Sloss 2016). Female adult beetles create brood galleries beyond the cambium inoculating the walls of the gallery with the fungus, *Fusarium* sp., as they bore into a host tree species (Eskalen et al. 2013). The fungus will grow and feed both the larvae and adults, eventually blocking the transport tissue of the host (Freeman et al. 2013; Mendel et al. 2012). This prevents movement of water and nutrients to the upper canopy causing associated branch dieback and tree mortality (Freeman et al. 2013; Eskalen et al. 2013; Mendel et al. 2012).

6.4 RESULTS OF INVASIVE ANIMAL STUDIES IN THE MSPA

There are many studies addressing invasive animals in the MSPA. The results and progress of a few of these studies are summarized below, and a more comprehensive list is provided in Table V2B.6-2.

In 2012, USGS began assessing native and nonnative turtles, as well as suitable habitat for pond turtles in coastal northern San Diego County (Brown et al. 2015). Before successful management can be implemented, the distribution and status of pond turtles and aquatic nonnatives had to be determined. USGS determined that nonnative turtles were more abundant than southwestern pond turtles within the study area. Southwestern pond turtles were detected at 2 sites, while nonnative turtles were detected at 18 sites, including the sites with the native turtles. Nonnative centrarchid fishes were detected at 16 sites, American bullfrogs were detected at 12 sites, and red swamp crayfish were detected at 12 of the sites. In contrast, the only native species beside the pond turtle that was detected was the Pacific tree frog. The study provided a summary of monitoring and management guidelines that can be used to sustain and improve pond turtle populations within the coastal watersheds of northern San Diego.

Table V2B.6-2. Summary of relevant Invasive Animal studies.

Topic/Species	Publication(s)	Summary
Parasitism, productivity, and population growth: response of least bell's vireo and southwestern willow flycatchers to cowbird control	Kus and Whitfield 2005	Cowbird control is a major aspect of recovery-oriented management for the endangered southwestern willow flycatcher and the least bell's vireo. Twenty years of cowbird trapping have reduced parasitism at the least Bell's vireo and southwestern willow flycatcher breeding sites. This trapping led to an 8-fold increase in vireos, but little change in abundance was observed for the flycatchers. Cowbird control interferes with the evolutionary processes necessary for establishment of genetically based natural defenses. From the study analysis, researchers suggest shifting away from long-term control programs and toward practices that emphasize restoration and maintenance of natural processes on which species depend.
Factors influencing the incidence of cowbird parasitism of least bell's vireo	Sharp and Kus 2006	Microhabitat is the most important habitat feature influencing the incidence of brood parasitism of least Bell's vireos. Dense cover may shield parental activity from the searching cowbirds. Habitat management should focus on increasing the density of understory vegetation.
Parasitism and gnatcatcher nest fates	Braden et al. 1997	Predation had a greater influence on gnatcatcher nest fates than parasitism. Approximately half of the potential impacts of nest parasitism on gnatcatcher nest fates were negated by depredation of parasitized nests. The modest gains in nest success from cowbird trapping were overwhelmed by a large decrease in nest success. The decrease in nest success was likely due to nest abandonment unrelated to parasitism.
The impact of free-ranging domestic cats on wildlife in the United States	Loss et al. 2013	A systematic review and quantitative estimate on mortality caused by cats in the United States.
Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands	Soule et al. 1988	Evidence from the study suggests that chaparral-requiring birds in isolated canyons have very high rates of extinction partially due to their low ability to move from place to place.
Use of matrix population models to estimate the efficacy of euthanasia versus trap-neuter-return for management of free-roaming cats	Anderson et al. 2004	Effective cat population control is achievable by euthanizing at least 50% of the population or by neutering greater than 75% of the population annually.

Topic/Species	Publication(s)	Summary
Variable effects of feral pig disturbances on native and exotic plants in a California grassland	Cushman et al. 2004	Study results indicated that feral pig disturbance had substantial effects on the community. Soil disturbances by pigs increased both exotic and native plant species richness. Pig disturbance led to a 69% reduction in biomass of exotic annual grasses in tall patches and a 62% increase in short patches. Native, nongrass monocots exhibited the opposite pattern. Native forbs were unaffected, but exotic forb biomass increased by 79%. Vegetation changes were likely due to the clearing of space by pigs.
Rooting and foraging effects of wild pigs on tree regeneration and acorn survival in California's oak woodland ecosystems	Sweitzer and Van Vuren 2002	Long-term study of the ecological effects of wild pigs on oak woodland ecosystems in California using multiple control plots using paired control plots. Soil disturbance significantly higher in areas of high pig density. Rooting significantly reduced aboveground plant biomass in oak woodland and may reduce forage availability. Rooting may significantly reduce survival of tree seedlings, limiting oak woodland regeneration.
Southwestern pond turtle study for TransNet grant	Brown et al. 2015	Pond turtles were detected at 2 sites while red-eared sliders were detected at 18 of the 62 sites surveyed. Six other nonnative species were detected in the study. Nonnative aquatic species were detected at 37 sites compared with the 5 sites where natives were detected. Threats from nonnative aquatic animals result in low population recruitment.
Joint estimation of habitat dynamics and species interactions: disturbance reduces co-occurrence of nonnative predators with an endangered toad	Miller et al. 2012	Results support that disturbance and species responses post-disturbance structure differences in co-occurrence of native toads with nonnative predators among sites in the stream systems studied.
Floral visitation by the Argentine ant reduces pollinator visitation and seed set in coast barrel cactus	LeVan et al. 2014	Floral visitation by ants affects pollination services when the invasive Argentine ant replaces a native ant species in a food-for-protection mutualism with the coast barrel cactus. Cactus bees spent less time in flowers of cacti occupied by the Argentine ant compared to those occupied by the native *Crematogaster californica.* The decrease in the duration of visits is likely the cause for the decrease in seed set per fruit by cacti occupied by Argentine ants, and the production of fewer seeds overall.

USGS researchers conducted a study that tracked the trends in breeding populations of arroyo toad within 3 occupied drainages to develop management action recommendations and evaluate the effectiveness of those actions (Brehme et al. 2011). This research and monitoring effort developed a probability of detecting arroyo toads that used a nonnative index as one of the inputs. Mosquitofish, bullfrogs, crayfish, and predatory fish were all detected threats to the arroyo toad, decreasing detection probability.

In a USGS study, scientists examined the relationship of vegetation surrounding nests and of vireo behavior near nests to the incidence of parasitism (Sharp and Kus 2006). Monitoring occurred annually at a long-term study site on the San Luis Rey River in southern California for 3 seasons between 1999 and 2003. Their data provide information for designing recovery strategies to minimize parasitism of the least Bell's vireo. From their study, they determined that microhabitat cover is the most important habitat feature influencing the incidence of brood parasitism of least Bell's vireos. Additionally, large trees can provide vantage points for perched cowbirds, increasing the likelihood of parasitism.

A USGS analysis of published and new information on long-term cowbird trapping programs determined that enhanced seasonal productivity due to cowbird trapping programs have led to an 8-fold increase in least Bell's vireo numbers (Kus and Whitfield 2005). However, southwestern willow flycatcher abundance remained nearly unchanged. Researchers suggest that cowbird control be reserved for short-term crisis management and be replaced, when appropriate, by practices emphasizing restoration and maintenance of natural processes on which the species depends on.

A study by LeVan et al. (2014) examined how floral visitation by ants affects pollination services when the invasive Argentine ant replaces a native ant species in a food-for-protection mutualism with the coast barrel cactus. Researchers discovered that cactus bees spent less time in flowers of cacti occupied by the Argentine ant compared to those occupied by the native *Crematogaster californica.* This decrease in the duration of visits is likely the cause for the decrease in seed set per fruit by cacti occupied by Argentine ants, and the production of fewer seeds overall.

6.5 MANAGEMENT AND MONITORING APPROACH

The overarching goals for addressing invasive animal species in the MSPA are:

(1) Protect intact, unspoiled habitat from new or expanding invasive animal species

(2) Detect new invasive species and new invasions early on and control them before they have a chance to establish

(3) Address invasive species using the response appropriate for the level of invasiveness ensuring higher-priority invasive animal species are addressed first

The approach for managing invasive animals is divided into 2 parts: general and species-specific. General invasive animal objectives focus on early detection and eradication across the MSPA. Species-specific objectives have been developed for those MSP species identified as at highest risk from loss due to invasive animals, and for which specialized objectives are required to ensure their persistence in the MSPA.

6.5.1 General Approach Objectives

Below is a summary of the management and monitoring objectives for the threat of invasive animals. For the most up-to-date goals, objectives, and actions, go to the MSP Portal Invasive Animal summary page: http://portal.sdmmp.com/view_threat.php?threatid=TID_20161207_1454.

Prepare an Invasive Animal Strategic Plan

In early 2017, SANDAG, USGS, and other agencies will begin developing a regional strategic plan for the management and monitoring of invasive animal species. The Invasive Animal Strategic Plan (IASP) will assess and rank nonnative animals using an assessment process that evaluates abiotic and biotic impacts, invasiveness, and distribution. Evaluating risk to determine the potential pool of taxa that could become direct or indirect risks is vital to the creation of the plan. After the nonnatives have been evaluated, they will be ranked on their threat level. High threat level species need to be addressed immediately for control or eradication, while species with a lower threat level may have a lower priority for removal.

The IASP will look at species at various geographic levels of invasion, including species that are outside of the region with the potential to spread into the region; species that are already in the region but only in the urban setting; and species that are in the region and have entered the wildlands. Some nonnative species may only be in the urban landscape, without a threat of crossing into natural areas, decreasing the urgency in removing them.

Several species outside of the region will be monitored by biologists and evaluated for their potential to spread into San Diego, as well as monitored for their potential threat to the region. These species include, but are not limited to, the following:

- Fox squirrel (*Sciurus niger*) – spreading from Los Angeles; a mostly urban species that also inhabits yards; potential risk to oak and jojoba in maritime succulent scrub habitat
- Sonoran whiptail lizard (*Aspidoscelis sonorae*) – found in parking lots in Orange County; parthenogenic species; risk of it hybridizing with native whiptails if it spreads to natural areas
- Wall lizard (*Podarcis muralis*) – spreading through urban Los Angeles; threat to the El Segundo Dunes blue butterfly (*Euphilotes battoides allyni)*

Assessing these species and their potential impacts, as well as other nonnatives even farther from San Diego, is a key component of early detection and rapid response. In addition, the plan will address biosecurity measures to reduce the unintentional spread of invasive species to Conserved Lands.

The IASP will address the San Diego nonnative wildlife species that are established in urban environments, nonnatives that are in urban environments but with the potential to spread to natural areas, and those that are already in natural areas. While, urban biodiversity includes many nonnatives, not all of those include an apparent risk. A few urban species that have been shown to harm native species include:

- Domesticated and feral cats – disrupt food web; disease transfer
- Opossums – may be passing disease
- Parrots – may be passing disease
- Argentine ants – disrupt food webs; disrupt pollination/reproduction

Some invasive species thrive in urban areas or the wildland urban interface, but many invasive species are completely disconnected from the urban environment. Included are many aquatic species and some terrestrial species, such as bullfrogs, crayfish, red-eared sliders, tiger salamander, invasive fish, wild turkeys (*Meteagris gallopava silvestris*), and feral pigs.

In addition to evaluating nonnative species and assessing their level of threat, the IASP will also identify the responsible parties for each species and at what level that organization is addressing the species. In developing the IASP, the collaboration will determine what species can be managed and which organizations are most appropriate for the management. It is important to work with other counties and urge them to address nonnative species before they spread further. The collaboration will also work with CDFW to update their list of prohibited species.

<u>Implement the Invasive Animal Strategic Plan</u>

The approach for managing invasive animal species is to follow the recommendations provided in the IASP, including adopting and implementing the recommended biosecurity measures. Early Detection and Rapid Response programs are the best way to manage invasive species with limited distributions where eradication is the goal. The goal for species that are abundant in localized areas is eradication within that geographical area (e.g., watershed, MU etc.) where management will significantly benefit MSP species. The goal for abundant and widespread invasive species is eradication in the areas where those species adversely affect narrow endemic plant species, primarily Category SL, SO, SS species.

Monitor Effectiveness of Implementing the Invasive Animal Strategic Plan

Monitoring the effectiveness of the IASP is a critical step in ensuring the most appropriate and effective actions are being implemented. This would include regular surveys and reports on the status of species spread or species reduction, in the case of species being actively controlled. Continued monitoring would allow land managers to update the list of priority species and report to the conservation community when suspected new invasives have entered the MSPA. Additionally, monitoring will determine what, if any, control measures that are not effective at controlling and/or eliminating target species.

Support Feral Pig Eradication Program

The SDMMP will continue supporting the Feral Pig Eradication Program and the partners involved with implementation.

Implement SHB Management Strategy

The approach for managing the shot hole borer is to follow the recommended actions provided in the SHB Management Strategy Plan (SANDAG 2016 *draft*). This includes working collaboratively with land managers, researchers, regulators, and funding agencies to implement common goals. The management strategy goal is to reduce expansion of the shot hole borer into new areas and manage known occurrences of the beetle.

Monitor Success of the SHB Management Strategy

Monitoring the success of the SHB strategy is an important step in determining the effectiveness of the recommended management actions. This information is imperative in adapting BMPs, a vital part of the strategy. Using monitoring data to revise and design new BMPs will allow for more effective control and management actions.

6.5.2 Species-Specific Approach Objectives

The impacts of invasive species on rare and endemic species can vary widely. While some invasive animals have a drastic impact on whole plant communities, some invasives have a disproportionate effect on certain native species. Species for which invasive animal goals and objectives have been identified as part of their management and monitoring approach are identified in Table V2B.6-3. Use the MSP Portal for the most updated list of species with Invasive Animals objectives.

Table V2B.6-3. MSP plant and animal species with specific invasive animal management and monitoring objectives.

Scientific Name	Common Name	Management Category	Summary Page Link
Plants			
Quercus engelmannii	Engelmann Oak	VF	https://portal.sdmmp.com/view_species.php?taxaid=19329
Invertebrates			
Euphyes vestris harbisoni	Harbison's dunn skipper	SL	https://portal.sdmmp.com/view_species.php?taxaid=707282
Amphibians			
Anaxyrus californicus	Arroyo toad	SO	https://portal.sdmmp.com/view_species.php?taxaid=773514
Reptiles			
Emys pallida	Southwestern pond turtle	SL	https://portal.sdmmp.com/view_species.php?taxaid=668677
Phrynosoma blainvillii	Blainville's horned lizard (Coast horned lizard, San Diego horned lizard)	VF	https://portal.sdmmp.com/view_species.php?taxaid=208819
Mammals			
Aquila chrysaetos canadensis	Golden eagle	SO	https://portal.sdmmp.com/view_species.php?taxaid=175408
Vegetation Communities			
Oak Woodland			https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_10
Riparian Forest & Scrub			https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_7
Torrey Pine Forest			https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_8

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