INTEGRATED ADAPTIVE WILD PIG MANAGEMENT PLAN

MITIGATING CONFLICTS BETWEEN WILD PIGS AND SENSITIVE RESOURCES WITHIN EAST BAY STEWARDSHIP NETWORK PROPERTIES

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INTEGRATED ADAPTIVE MANAGEMENT PLAN FOR WILD PIGS WITHIN EAST BAY STEWARDSHIP NETWORK LANDS

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East Bay Stewardship Network

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SECTION 1: FOREWORD

Wild pigs (*Sus scrofa)* are one of the most invasive species of mammal worldwide and within the U.S. Native to parts of Europe, Asia, and Africa, the current wild pig population in the U.S. is made up of escaped domestic pigs (feral pigs), introduced Eurasian boar, and hybrids between the two (*hereafter* "pigs"). Domestic pigs were introduced to the state of California in the 1700s as livestock, and a landowner introduced them to Monterey County in the 1920s for hunting. Wild pigs have become a significant issue in California, with their presence now recorded in 56 out of the state's 58 counties. This widespread distribution is primarily due to domestic pigs escaping into the wild, illegal translocations by individuals seeking to enhance recreational hunting opportunities, and the natural invasive spread of these animals, through their adaptability.

Pigs cause significant ecological and economic impacts through rooting, wallowing, and depredation behaviors. Within the region surrounding the San Francisco Bay Area (*hereafter* "Bay Area") of California, wild pigs threaten the existence of valuable and sensitive ecological and human water resources (Frederick 1998). The East Bay Stewardship Network (*hereafter* "EBSN" or "the Network") is a coalition of five agencies (members) in Alameda, Contra Costa, Santa Clara, and San Joaquin Counties that collectively manage over 272,000 acres of public land in the East Bay. Network partner organizations are responsible for the ecological conservation of wildlife, habitats, water, and other resources within those properties. While the properties managed by the Network are not all adjacent, due to their proximity, the pig populations that use these areas are likely interconnected, warranting a regionally collaborative and well-coordinated management effort.

Native predators such as coyotes (*Canis latrans*), black bears (*Ursus americanus*), and mountain lions (*Puma concolor*), have been documented to depredate primarily younger age classes of pigs. However, depredation by these species is not significant enough to control pig population growth (Barrett 1971, Sweeney *et al*. 2003). Additionally, recreational hunting is not sufficient to effectively control growth of pig populations. Pigs are very difficult to exclude from areas with desirable resources. On public lands surrounded by urban development, management tools such as recreational hunting and trapping are often infeasible due to safety and legal constraints. Effective lethal removal is time-intensive and costly as wild pigs are resilient, adaptive, and may reproduce quickly following population control efforts. Due to high fecundity and survival, as many as 60-80% of pigs within a population may need to be removed to keep the population from growing (Hone and Robards 1980, Klinger *et al*. 2011). The growth rate of pig populations can vary regionally and annually, based on availability of resources such as food and water and the amount of suitable habitat available for population expansion.

Many pig management programs have evaluated the acceptable level of damage or loss, but that has mostly pertained to crops or other economic properties. The Network is responsible for protecting valuable natural resources, which include state and federally listed species, and human water sources. Assessing and describing acceptable levels of damage or loss for these critical resources is far more complex. Given that any loss resulting from a non-native, invasive species like wild pigs could have significant and potentially irreversible impacts, the acceptable level of loss may be zero. The largest challenge for preventing all damage to natural resources from pigs, may be identifying and maintaining enough, and long-term, funding to support adequate pig population control or eradication.

For these reasons, members of the Network have relied on contracted professional pig removal services to control pigs and protect resources for more than 30 years at some properties. Although the level of effort and methods being used have not changed, more pigs have been removed in recent years. This may indicate that the number of pigs within Network properties is increasing due to insufficient population control at the current level and type of effort within the program. However, more information is required. Wildlife Innovations (WI) presents this comprehensive management plan (*hereafter* “the Plan”) to assist the Network with enhancing collaborative pig management efforts across their properties and evaluate the effectiveness of current pig removal strategies.

SECTION 2: PURPOSE OF THIS PLAN

This document is a collaborative effort between Network members to foster a more coordinated and effective approach to managing wild pig populations within the Network's properties and provides a scientifically backed strategy so that a collaborative and adaptive process can be implemented. The Plan provides background information on pigs and their use of Network properties; incorporates previous removal data and methods for mitigating conflict and threats to natural resources, property, and human health and safety; and provides both broad and specific recommendations to be considered across the Network as a whole, Landscape Units (Fig. 1), and individual properties. Additionally, the Plan provides guidelines to foster education and outreach efforts to park users, Network staff, lessees of Network properties, and contracted pig management entities so that these methods, and others developed from them, can be further supported in both the short and long term. The adaptive management strategy also incorporates analyses of lessons learned during the early years of this program to help improve the efficiency of future efforts and facilitate testing and implementation of innovative methods as they become available. This process is expected to increase effectiveness and efficiency of pig control, thereby minimizing the cost of a long-term mitigation program. In addition, by developing a program aimed at reducing the the number of pigs that need to be removed through effective implementation of nonlethal strategies where possible and feasible; the program would best support the humane treatment of wild pigs.

SECTION 3: SITE AND NETWORK INTRODUCTION

The Network is a coalition of land managers in the Bay Area that collectively manage properties totaling over 25% of the land area of Alameda and Contra Costa counties (Fig. 1). The Network comprises five entities: the East Bay Regional Park District (EBRPD), California State Parks (“CSP” or “CA Parks”), Contra Costa Water District (CCWD), East Bay Municipal Utility District (EBMUD), and San Francisco Public Utilities Commission (SFPUC). Properties managed by Network organizations are divided into two Sub-Regions and five Landscape Units (LU) to facilitate management and associated communications regionally (Fig. 1). The Network protects over 272,000 acres of land within the east Bay Area, and the Network’s primary goals are to understand the effects of climate change, altered fire regimes, invasive species (e.g., wild pigs), and other environmental impacts on their lands. To better understand the implications of such threats and manage lands across jurisdictional boundaries, these entities work collaboratively towards shared goals.

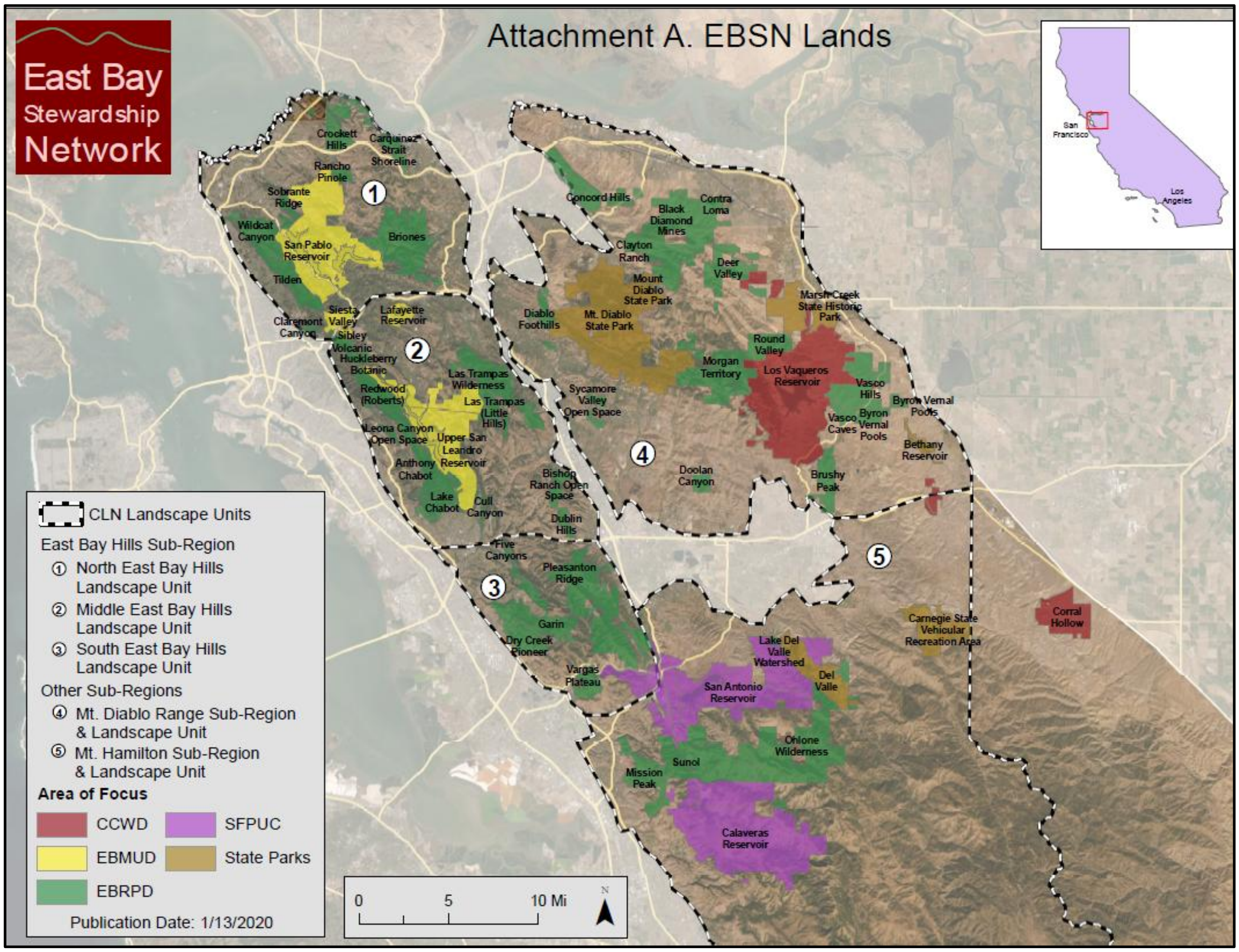

Figure 1. Map of EBSN lands including Landscape Units, Sub-Regions and areas of focus.

East Bay Regional Park District

The East Bay Regional Park District consists of 74 parks which include more than 125,000 acres in both Alameda and Contra Costa counties (EBRPD 2023). These lands are protected and managed by the EBRPD, providing natural habitat for outdoor recreation and ethical environmental education (EBRPD 2023). The parks provide suitable habitat for over 500 species of wildlife and are specifically managed for the protection of threatened and endangered species (EBRPD 2023). Over 60 special status species inhabit these parks, including the California tiger salamander (*Rana draytoni*) and California red-legged frog (*Rana draytoni*), along with multiple species of rare plants; EBRPD 2023). In addition to providing these special status species with protected land, the park district's dedicated staff closely monitor these species to help maintain and promote a healthy ecosystem (EBRPD 2023).

In EBRPD, pig presence is damaging to native ecosystems (EBRPD personal communication). They wallow in seeps and springs, damaging spring developments and the associated pipelines. They also negatively impact wetland vegetation. Pigs root up geophytes under oaks and in wetlands. In some years, multiple square miles get tilled by pigs. In some parks, pigs have dug up native grasslands, converting the landscape to non-native weeds.

Pigs have also had human impacts at EBRPD properties. There has been at least one report of a backpacker being attacked by a boar. In addition, during the August 2020 SCU Lightning Complex fire, firefighters were attacked by pigs. A grazing tenant at Bishop Ranch no longer keeps calves at his ranch due to potential pig predation (EBRPD personal communication).

California State Parks

California State Parks (CSP) contains the largest recreational, natural, and cultural heritage holdings of any state-run agency in the country (CSP 2023). This includes 280 state parks, 340 miles of coastline, 970 miles of lake and river frontage, and numerous other properties (CSP 2023). The goal of CSP is to maintain, manage, and protect California's collection of culturally and environmentally sensitive structures and habitats, as well as threatened plant and animal species (CSP 2023).

Mt. Diablo State Park and Carnegie State Vehicular Recreation Area (SVRA) are two CSP properties within the Network and are focal State Parks for this management plan. Mount Diablo is one of the highest points within the Bay Area, standing 3,849 feet tall at its peak (CSP 2023). This 20,000-acre park is home to 160 miles of trails throughout several different habitat types. Consisting of oak and riparian woodlands, chaparral, grasslands, and volcanic rock at the summit, the park is home to a diverse group of wildlife, including the threatened California red-legged frog, Alameda whipsnake (*Masticophis lateralis euryxanthus*) and California tiger salamander (CSP 2023).

At. Mt. Diablo State Park, pigs frequently root and wallow in several ponds known to be inhabited by sensitive species (CSP personal communication). The entire park property is classified as critical habitat for the listed Alameda whipsnake. Feral pig damage is widespread throughout the park but the extent of impacts to whipsnake habitats are unknown. There are also several listed plant species in the park, including the Mt. Diablo fairy-lantern (*Calochortus pulchellus*), Mt. Diablo buckwheat (*Eriogonum truncatum*), and Brewer's western flax (*Hesperolinon breweri*) that have the potential to be impacted by pig disturbance. Pigs have also been vectors for spreading weeds. Park staff have observed areas of native grasslands transformed into annual grasslands in short periods of time due to pig activity, reducing native biodiversity.

Visitors and staff often encounter pigs in remote locations, and there have been reports of aggressive pigs charging park visitors (CSP personal communication). Rooting has damaged pipelines and various other facility infrastructures. Rooting and wallowing have heavily impacted and destroyed some cultural resources including artifacts, structures, and other historical features. Some sites have been heavily damaged, prompting resource condition assessments. Pigs have been documented rubbing against the sides and walls of historic structures, causing damage to building supports, frames, and foundations.

Carnegie SVRA is one of the nine State Vehicular Recreation Areas maintained by CSP. Located within Alameda and San Joaquin counties, Carnegie SVRA has over 1,300 acres of land with 80 miles of accessible riding trials (CSP 2023). It features rolling hills with steep canyons that provide challenging terrain for riders but is also home to several federally listed threatened species, including the California red-legged frog, western spadefoot *(Spea hammondii*), Alameda whipsnake, California tiger salamander, and includes critical habitat for the San Joaquin kit fox (*Vulpes macrotis mutica*; CSP 2018). Habitat conditions are carefully monitored by park staff to ensure protection protocols are being met (CSP 2018).

At Carnegie SVRA, pigs frequently traffic campsites and day use areas during off-hours (CSP personal communication). They knock over trash bins in search of food and damage facilities, resulting in the need for additional maintenance. Pigs also frequently root and wallow in ponds known to be inhabited by sensitive species. As at Mt. Diablo State Park, cultural resources have been damaged due to pig presence.

Contra Costa Water District

Formed in 1936, the Contra Costa Water District (CCWD) is one of the largest urban water districts in California, responsible for delivering high-quality, clean drinking water to roughly 520,000 people in the central and eastern parts of Contra Costa County (CCWD 2023). Water is pulled from the Sacramento-San Joaquin Delta through four intake points and conveyed to reservoirs located throughout eastern and central Contra Costa County or to Los Vaqueros Reservoir and Contra Loma Reservoir for storage. Water is pumped from those storage facilities to residents in Contra Costa County.

East Bay Municipal Utility District

The East Bay Municipal Utility District (EBMUD) provides the region's residents with water and wastewater treatment. Services include drinking water for 1.4 million people in Alameda and Contra Costa counties and wastewater treatment for 740,000 customers in the East Bay (EBMUD 2023). Drinking water is sourced from Pardee Reservoir, located within the Mokelumne watershed. EBMUD's East Bay and Mokelumne watersheds provide habitat for a diverse group of native California species. EBMUD's East Bay watershed is protected by the EBMUD Low Effect East Bay Habitat Conservation Plan (HCP) and the Mokelumne watershed is protected by the EBMUD Safe Harbor Agreement (EBMUD 2023). The EBMUD HCP covers species such as the Alameda whipsnake, California red-legged frog, rainbow trout (*Oncorhynchus mykiss*) and western pond turtle (*Actinemys marmorata*). California tiger salamanders, California red-legged frogs, and the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) are three federally threatened species that have received targeted restoration efforts within the Mokelumne watershed (EBMUD 2023). Restoration efforts were made possible with the safe harbor agreement between EBMUD and US Fish and Wildlife Service (USFWS).

EBMUD has been documenting feral pig damage at its East Bay watershed since the early 1990s (EBMUD personal communication). Pig damage has occurred primarily at the Upper San Leandro Reservoir watershed where it has been significant and persistent over the past three decades. Most of the damage observed has been in the form of rooting and wallowing in wetlands, creeks and along reservoir margins. These behaviors impact EBMUD's mission of providing a safe, clean drinking water supply and preserving and protecting sensitive native habitats.

Negative impacts to water quality have been observed in the Upper San Leandro Reservoir watershed which could impact EBMUD's drinking water supply (EBMUD personal communication). Feral pigs can introduce bacteria and fecal matter into streams and reservoirs, which can lead to elevated nitrogen levels, decreased dissolved oxygen, and introduced pathogens in the drinking water supply. Pigs have been observed contributing to siltation and contamination in streams and wetlands due to rooting and wallowing along stream banks and wetland habitats. These behaviors may ultimately harm freshwater fishes, amphibians, and invertebrates in these aquatic habitats including rainbow trout.

Feral pigs have damaged sensitive plants and sensitive habitats in the watershed (EBMUD personal communication). Rooting and wallowing has been observed to cause excessive erosion, impacting riparian vegetation and destabilizing channel beds or banks. In addition, pig wallowing and rooting in watershed ponds may decrease hydroperiod duration and lead to amphibian larvae stranding.

San Francisco Public Utilities Commission

The San Francisco Public Utilities Commission (SFPUC) is the main provider of water, power, and sewer services to the City of San Francisco. The SFPUC also provides wholesale water to three Bay Area counties, and hydroelectric and solar power to residents and businesses of San Francisco as part of the *CleanPowerSF* program (SFWPS 2023). The primary mission of the SFPUC is to provide high quality, efficient, and reliable water, power, and sewer services in a manner that is inclusive of environmental and community interests, and that sustains the resources entrusted in its care (SFWPS 2023). Water supplies are provided by three main watersheds: the Peninsula watershed, the Alameda Creek watershed, and the Upper Tuolumne watershed. The Alameda Creek watershed is 36,000 acres and includes two reservoirs, San Antonio Reservoir and Calaveras Reservoir. The SFPUC manages the watershed under the Alameda Watershed Management Plan which seeks to apply best management practices for the protection of water and natural resources. Consisting of oak and riparian woodlands, shrub communities, chaparral, and grasslands, the Alameda Creek watershed supports rare plants and habitat for special status wildlife species such as California red-legged frog, foothill yellow-legged frog (*Rana boylii*), California tiger salamander, and Alameda whipsnake.

Damage due to rooting and digging by pigs at SFPUC has included impacts to natural seeps and springs, spring developments and associated pipes, and negative impacts to native wetland vegetation, grasslands, and areas under oaks.

SECTION 4: IMPACTS FROM WILD PIGS

The history of destruction caused by pigs is well documented with reports of predation of calves as far back as 1505 (Mayer and Brisbin 2009). The United States Department of Agriculture (USDA) has called wild pigs “ecosystem engineers,” meaning that they change the environments they exist within (USDA 2020). Pigs may trample native plants, change water quality, and affect runoff in valuable wetland and riparian habitats by wallowing and rooting. Additionally, they can reduce tree diversity in forests and shift plant composition in grasslands, both of which can negatively impact native and listed wildlife species. Pigs can also transport invasive plant seeds into areas where sensitive native plants exist, creating habitat type conversion (Glow *et al*. 2020).

The primary means of environmental damage caused by pigs is from rooting behavior (USDA 2020). Rooting is a foraging strategy during which pigs use their snouts to dig and overturn soil (Frederick 1998). Pig wallowing, rooting, and foraging behavior can be extremely destructive to ecosystems and the biological resources within them. Rooting causes damage to native plants and irrigation systems, leading to soil erosion (Frederick 1998), and may contribute to increases in exotic annual grasses and exotic forbs (Cushman *et al*. 2004, Kotanen 1995). Pig consumption of acorns can decrease both abundance of acorns and survivorship of oak seedlings, which depresses oak recruitment (Sweitzer and Van Vuren 2002). Through consumption of those native resources, pigs also indirectly negatively impact native wildlife that also rely on acorns, such as black bear (*Ursus americanus*) and mule deer (*Odocoileus hemionus*) and may steal the caches of small mammals that depend on hard mast crops for survival (Cambell and Long 2009).

Their omnivorous diet and predatory behavior contributes to the decline of native wildlife populations and exacerbates the challenges of conservation efforts, as pigs will prey on the eggs and young of ground-nesting birds, mammals, and reptiles, and will consume small vertebrates (Jolley *et al*. 2010, USDA 2020). Additionally, pig foraging can cause loss of extensive areas of ground cover and litter layers in sensitive habitats (Chavarria *et al*. 2007). For these reasons, pigs have the potential to displace a variety of sensitive wildlife species (USDA 2020).

Wild pigs have a substantial negative economic impact on agriculture in the U.S. (Seward *et al*. 2004). When available, wild pigs prefer agricultural crops (e.g. corn, soybeans, and grains) due to the high caloric content in those plants (Mayer and Brisbin 2009, VerCauteren *et al*. 2020). As a result, wild pigs often damage crops by direct consumption, trampling, or destroying the seed beds by rooting (VerCauteren *et al*. 2020). USDA's Animal Plant and Health Inspections Service (APHIS) estimates that wild pig damage and subsequent control costs the U.S. agricultural industry $2.5 billion annually (USDA APHIS 2024). Since pigs typically exist in groups (sounders), multiple individuals foraging simultaneously can rapidly damage agricultural crops. Pigs can also directly depredate livestock, taking the young of domestic sheep, goats, and cattle (Choquenot et. al. 1996, Seward *et al*. 2004, Ditchkoff and Mayer 2009). In 1991, livestock owners from California and Texas reported to USDA APHIS that 1,473 sheep, goats, and exotic game were killed by wild pigs (Barrett and Birmingham 1994). While there is minimal agriculture on EBSN properties themselves, there are agricultural operations and home landscaping adjacent to EBSN lands, which are a concern and generate complaints regarding pig presence.

Pigs are known to carry 30 diseases and 37 parasites that can be transmissible to people, livestock, domestic animals (Seward *et al.* 2004), and wildlife. Some of those diseases include pseudorabies, bovine tuberculosis, several strains of brucellosis, foot and mouth disease, swine brucellosis, and classical swine fever (Christie *et al*. 2014, UC IPM 2024). The threat of brucellosis transmission is the biggest concern for livestock, which causes populations to abort fetuses (Davis 2014). With an increasing wild pig population, the threat of disease transmission grows with it (Christie *et al*. 2014). Disease outbreaks have been traced back to wild pigs (Christie *et al*. 2014, Barrett and Birmingham 1994).

Wild pigs carry five major pathogens that can enter waterways and infect humans. These include *E.coli*, *Campylobacter*, *Salmonella*, *Cryptosporidium*, and *Giardia* (UC IPM 2024). Pigs also increase turbidity in water sources by stirring up sediment, increasing concentrations of pathogens in the water column and downstream by releasing bacteria contained within. Sediment serves as a source for bacteria, where it survives well following deposition from external sources (EPA 2006, Brashaw *et al.* 2021). Turbidity can also protect waterborne pathogens during chemical disinfection processes used in water treatment facilities.

Wild pig collisions with vehicles are also occurring more frequently in the United State as wild pig populations continue to grow (Mayer and Johns 2007). The estimated cost of property damage due to vehicle collisions with pigs in the U.S. is $36 million annually (Mayer and Johns 2007).

Pigs can cause extensive economic damage to human-altered areas, such as parks, landscaped lawns, residential areas and may threaten human safety directly (e.g., attacks by pigs) and indirectly (e.g., disease transmission). Rooting behavior can cause damage to sprinkler and irrigation systems, as pigs try to access the water inside of pipes (Tisdell 1982). Damage to fencing can result in livestock escaping, allowing predators to gain access to livestock, and economic loss to landowners due to replacement or repair costs (Mapston 2004).

SECTION 5: PIG MANAGEMENT NEEDS

Pigs have been present on Network properties at least since the 1990s, and pig population control has been conducted on some of the Network properties at least that long based on data received from the Network. Ample food, cover, and water resources exist within Network properties for pigs to thrive. Despite year-round efforts to remove pigs within Network properties, with a similar level of pig removal effort reported to have been conducted annually, the number of pigs removed each year has increased during the last 10 years, with a more dramatic increase during the last five years. The increase may indicate that the pig population within Network properties is growing and that the type and/or amount of pig removal effort is insufficient to effectively control pigs.

The Network seeks to protect its open spaces as habitat for listed threatened and endangered species of plants and animals, for clean and dependable drinking water, and for safe and equitable recreational access. Given the adverse ecological impacts caused by pigs, it is imperative for the Network to continue to develop and operate an effective pig management program to reduce the risk of economic and environmental impacts, including negative impacts to sensitive habitats and rare plants, predation of and competition with native wildlife, spread of invasive plants, potential impacts to cultural resources, water quality and erosion, and human and wildlife health threats from diseases and parasites.

Due to proximity of Network properties to each other, and the high mobility of pigs, many network properties likely share some of the same pigs. Where sufficient barriers do not exist (e.g. large freeways, or dense urban development without sufficient green space as travel corridors for pigs), pigs likely move between Network properties. Movements may occur to avoid management pressures within some properties, or due to differences in available food sources. Since pigs likely move freely between many Network properties, pig management should be well coordinated and conducted in concert between Network members with properties that exist within proximity.

This Plan outlines both short- and long-term program goals, detailing specific steps to enhance data collection using the current resources available within the program. Additionally, it recommends further resources and program components necessary to support the achievement of these goals, ensuring a more effective and sustainable approach to managing wild pig populations. To support development of an effective Plan, the following facets and tasks were completed:

1. Review of literature focused on the natural history of wild pigs, their impacts on native wildlife and vegetation communities, and effective control and management.
2. Review of wild pig distribution throughout Network lands, using data recorded from pig control efforts, community science information.
3. Generation of a list of parks where wild pig presence has been confirmed within the past five years and where management efforts need to be focused.
4. Population-level analysis and review of past, present, and projected wild pig populations in the region.
5. Identification of ways to establish low-effort and sustainable monitoring of wild pig populations, movement, and distribution within Network properties.
6. Identification of the costs and effort necessary to include a satellite tracking study, as a part of wild pig management efforts on Network properties, to better understand their movements and inform targeted management efforts in the region.
7. Development of a ranking system to identify priority open spaces/parks, based on available data, with recommendations of high-priority parks to focus pig control or eradication efforts.
8. Review of the methodology of current short-term pig population control efforts to identify modifications that could increase efficacy of implementation, monitoring, and database management.
9. Development of a more streamlined pig damage reporting system and materials to educate Network agency staff, ranchers, and volunteers to report pig damage in a timely manner.
10. Recommendations for long-term management goals, including feasibility of pig fencing within certain areas, ways to adaptively manage temporal increases in pig populations,

and to reduce impacts to sensitive biological resources.

11. Identification of ways to improve regional collaboration and coordination regarding pig management.

Section 6: Wild Pig Biology and Ecology

Pigs are the most abundant free ranging, introduced, ungulate species in the U.S. (Hernandez *et al*. 2018, Decker 1978). Pigs are native to large parts of Europe, Asia, and North Africa but are not native to the western hemisphere. Humans have introduced pigs to the western hemisphere repeatedly. The initial introduction is thought to have occurred between 750-1000 A.D. on the Hawaiian Islands (Joesting 1972, Smith and Diong 1977), and domestic swine were estimated to have been introduced to continental North America in 1539 (Barrett and Birmingham 1994). The current pig population in the U.S. is made up of domestic pigs gone feral, Eurasian wild boar, and hybrids between the two (Wood and Barrett 1979). Both domesticated pigs and Eurasian wild boar have been intentionally released by both private and public entities into the wild, in at least 20 states (McKnight 1964), with the associated invasive spread resulting in pigs moving into at least 35 of the 50 states (Corn and Jordan 2016).

Hybrids of wild boar and domesticated pigs were introduced into California as early as the 1700s, by the Spanish (Finzel and Baldwin 2015), and again in 1925, when Eurasian wild boar were introduced in Monterey County (Pine and Gerdes 1973, Barrett and Birmingham 1994). Pigs have very high reproductive rates and can adapt to and survive within a wide range of habitats. As a result of those and other factors, pigs now occur in nearly all of California (56 of 58 counties), where they exist in one of their largest and widest geographic distributions documented (Hutton *et al*. 2006, West *et al*. 2009, USDA 2015, Lewis *et al*. 2017).

<u>Lineage and Physical Characteristics</u>

The population of wild pigs in North America includes pure feral pigs (escaped domestics), pure Eurasian wild boar (only found in Michigan, New Hampshire, and Canada), and wild boar/feral pig hybrids (Mayer and Brisbin 2009, VerCauteren *et al*. 2020). However, these different lineages are all the same species (*S. scrofa*). The wild boar is the primary wild ancestor of most modern domestic pig breeds (Mayer and Brisbin 2009). In the U.S., when wild boar, domestic pigs, or their hybrids are found in the wild, they are collectively referred to as wild pigs. This broad classification includes all three lineages, reflecting their shared characteristics and the challenges they pose to ecosystems and management efforts.

Although the three lineages of wild pigs all share the same body structure: a barrel-like body, short neck with a long head, short legs, and a disk-like snout (Mayer 2009), they exhibit a wide range of hair lengths, from short to long, with the extent of body coverage varying between individuals (Mayer 2009). Additionally, the coat of wild pigs can differ in color and pattern (e.g., black, brown, red, white, spotted, belted; Mapston 2004), as can the cranial and mandibular measurements of the skull (VerCauteren *et al.* 2020). This variability can be influenced by factors such as genetics, environmental conditions, and the specific lineage of the pig, leading to diverse appearances among wild pig populations.

The Eurasian wild boar has the largest body size of the three lineages with longer legs, larger heads, and a larger head-to-body ratio (Mapston 2004). They have the shortest tails of all wild pigs, a coat that usually is light brown to black in color, and the longest bristles with multiple splits on the tips (Mapston 2004). Hair bristles on feral pigs are not as thick as those on Eurasian wild boars but are thicker than hybrids and split at the ends (Mapston 2004). Most of the characteristics of hybrids resemble either feral pigs or wild boars (e.g., color and coat pattern) and have bristles longer than feral pigs but shorter than wild boar (Mapston 2004).

Male pigs are overall larger than females with a larger head, higher shoulders, and much larger canine teeth that protrude from the mouth, also called tusks (Herring 1972).

Senses

Pigs possess good eyesight, less developed hearing, and an excellent sense of smell (Frädrich 1974, Mayer 2009). They rely on these three senses, in addition to touch, to navigate the landscape and detect predators or adversaries (Mayer 2009). In open areas, pigs have been documented identifying and fleeing from humans at distances over 1.5km (Kramer 1971). In ideal conditions, pigs can detect humans by scent downwind up to 500 to 600 meters away (Banoğlu 1952).

Social Behavior and Social Unit Organization

Wild pigs are gregarious in nature, forming social relationships and associations early in life with their littermates, which may continue into their adult lives (Graves 1984). Typical social units are maternally based, consisting of several female pigs (sows) and their offspring, along with male pigs (boars) when sows are seeking mates. Sows may become solitary shortly before giving birth, often reforming into typical social units (also called sounders) afterwards. The young pigs in these groups predominantly consist of same-age individuals (Eisenberg and Lockhart 1972).

Male pigs can exhibit aggression towards each other, which is typically associated with competition for breeding females or, less frequently, for food resources. Aggression can occur between boars of all ages and at all periods of the year but occurs more frequently among more mature individuals and during peaks in breeding (Frädrich 1974, Mayer 2009). Adult boars are aggressive towards each other during competition for estrous sows but do not compete for anestrous females.

Pigs may be active during the day, if hunting or other pressure from humans is infrequent. Pigs typically shift behavior as hunting pressure increases. With moderate hunting, pigs tend to bed down around sunrise and become active again in late afternoon. In areas with heavy hunting pressure or human presence, pigs are often nocturnal. Depending on pig density and abundance of cover, wild pigs tend to leave an area where hunting pressure becomes severe (CDFW 2024).

Reproduction and Population Dynamics

The fecundity of wild pigs is a strong driver for population growth and population recovery following management efforts. Boars can reach sexual maturity at just five months of age and begin breeding between six and 18 months of age, while sows reach sexual maturity between six and 10 months of age (Kinsey 2020). Sows frequently exhibit two estrous periods, once in summer and again in the fall (Mauget 1981). They have a gestation period of 115 days and can breed year-round (Mayer and Brisbin 2009). Pregnant sows typically build nests within one day of giving birth (Mayer *et al*. 2002). Each sow can produce between three and eight live fetuses per litter (Mayer and Brisbin 2009). The female pigs may combine litters, where multiple adult females care for young produced together, early in their offspring's life (Graves 1984). For these reasons, most pig populations have a high reproductive potential.

Wildlife populations exhibit density dependence in relation to carrying capacity (Bowyer *et al.* 2014), and when populations are reduced below carrying capacity, compensatory population growth occurs through a combination of increases in recruitment, survival, and fecundity (Caughley 1977). The extreme reproductive capacity of female pigs makes the likelihood of a compensatory response to lethal management even greater and has been documented to nullify increased population control efforts (Hanson *et al.* 2009, Adams *et al*. 2019).

Home Range, Foraging Behavior, and Habitat Selection

Pig home ranges, the spatial area that they utilize, vary in size by sex, subspecies of wild pig, season, temperature, water scarcity, and forage availability. Sounders control territories consisting of mutually exclusive core blocks, and variably overlapping home ranges. Although home ranges may overlap, sounders exhibit territoriality, generally avoiding each other by utilizing different spaces or at different times (Gaston *et al.* 2008, Sparklin 2009, Kilgo *et al.* 2021). Although still predominantly avoiding each other, increased food availability has been found to increase overlap in home range (Kilgo *et al.* 2021). Home ranges average between 1.1 and 5.32 km^2 within North America (Kurz and Marchinton 1972, Singer *et al*. 1981, Baber and Coblentz 1986, Boitani *et al*. 1994, Christie *et al*. 2014). Pigs in the state of California have an average home range size of 2.3 km^2 (Sweitzer *et al*. 2000). Sows typically reduce the size of their home range when they prepare to give birth (Kurz and Marchinton 1972).

Although pig diet varies seasonally based on the abundance and availability of food resources, approximately 88% of year-round food intake is plant material (Mayer 2009). Within Henry Coe State Park, California, Loggins *et al*. (2002) found that fall was the only season that showed significant variation in wild pig diet. During the remainder of the year, primary diet components were herbaceous vegetation. During fall, acorns were the primary food source, but dietary composition also included more animal matter than during other seasons. The increase in animal matter in pig diet was hypothesized to be due to the low protein content of acorns, and as a result pigs were consuming more items to supplement protein intake. Pig diets during the winter months are predominantly mast or roots (Wood and Roark 1980, Mayer 2009), but during years of mast failure, roots are the prominent food source (Scott and Pelton 1975).

Pigs are habitat and omnivorous dietary generalists that thrive in a diverse set of environments and adapt to ecological pressures (Ilse and Hellgren 1995), with these factors contributing to their wide distribution. As generalists, pigs have been observed drastically altering their diet and habitat use to shift to available resources. Pigs require habitat that includes reliable forage resources (e.g., acorns, nuts, and other mast produced during the fall and winter in habitats composed of woody vegetation such as trees or shrubs), water, cover, and shade (Pullar 1950, Singer and Ackerman 1981, Barrett 1982, Baber and Coblentz 1987, Choquenot *et al.* 1996). Habitat preference has been shown to differ significantly depending on the season, resulting in specific habitats being utilized to varying extents at various points throughout the year (Baber and Coblentz 1986). For example, in agricultural dominant ecosystems, pigs may fill large portions of their diet with the most widely available crop in the region (Herrero *et al.* 2006). Similarly, pigs have been documented in other habitat types shifting diets to reflect the most available food sources (Baber and Coblentz 1987).

Some studies documented that pigs prefer riparian areas and swampy bottomlands due to presence of water for thermoregulation (Dexter 1998, Gaston *et al*. 2008). Water is an essential habitat characteristic as pigs lack the sweat glands necessary to regulate their own temperatures (Bracke 2011). Areas of habitat that contain vegetation that provides both cover and mast production are selected by pigs more often than areas that do not contain both resources (Ilse and Hellgren 1995, Dexter 1998, Mersinger and Silvey 2007).

In California, studies have found that pigs are at their highest abundance in oak woodland and oak grassland or savannah habitats, biodiversity hotspots documented as important habitat to a variety of other species and are present in the central and north coast regions of the state (Garrison and Standiford 1996, Myers *et al*. 2000, Sweitzer and McCann 2007). Oak woodlands, prior to 2003, were estimated to occupy four million hectares in California (Griffin 1977, Bolsinger 1988). Both habitat types are characterized by a dominant oak overstory but differ in their density.

Oak savannas have a lower percentage of canopy cover and therefore, a greater percentage of grass understory, whereas oak woodlands have denser canopy cover and sometimes a shrub understory (Thilenius 1968, Veseley and Rosenburg 2010). Annual grasses comprise most of the understory vegetation in both habitat types (Holmes 1990). These habitats are typically bordered by high elevation conifer-dominant forests and low elevation grasslands (Allen-Diaz *et al.* 2007).

The oak woodlands and grasslands of coastal California are dominated by coast live oak (*Quercus agrifolia*) or Oregon white oak (*Quercus garryana*). Other oak species in California include blue oak (*Quercus douglasii*), valley oak (*Quercus lobata*), interior live oak (*Quercus wislizenii*), engelmann oak (*Quercus engelmannii*), canyon live oak (*Quercus chrusolepis*), black oak (*Quercus kelloggii*), and island oak (*Quercus tomentella*). Of those species, valley oak, blue oak, interior live oak, and Engelmann oak are found within oak savannas (Pavlik *et al.* 1991). In addition to oak woodlands, pigs have been documented in arid portions of Oregon to also show preference for mixed-conifer forests and chaparral shrublands (Coblentz and Bouska 2007).

The adaptability of wild pigs allows them to thrive in a wide range of habitats from marshlands to mountain ranges, but they generally don't occur in areas with sub-freezing temperatures (Barrett and Birmingham 1994). Although pigs mostly prefer wooded forests, they will occasionally appear in open ranges in less human populated areas (Barrett and Birmingham 1994).

Seasonal Shifts in Habitat Use

Pigs are known to adapt their spatial distribution in response to seasonally available food sources, such as agricultural crop seasons or hard mast production (Hayes *et al*. 2009, Ballari and Barrios-Garcia 2014). Pigs are dietary omnivores and exhibit extensive dietary plasticity when in differing environments, exposed to threats, and when exposed to food source availability fluctuations (Hayes *et al*. 2009). They have been documented shifting dietary preferences to primarily consume crops, when present in agricultural dominated habitats, during seasonal increased crop production (Schley and Roper 2003; Ballari and Barrios-Garcia 2014).

In non-agricultural habitats, pigs have also been documented shifting diets seasonally to reflect changes in availability of food sources coinciding with wet and dry seasons (Baber and Coblentz 1987). Additionally, pig movement is influenced by seasonal shifts in water distribution and vegetation cover.

In addition to climatic season (e.g., spring), pig hunting seasons (distinct periods of time in which recreational hunting is either more or less frequent) have been documented to significantly impact habitat preference (Gaston *et al.* 2008). In the same study, pigs preferred wetland and shrub habitats during the low-pressure hunting season and shifted to prefer pine forests and shrub habitats during the high-pressure hunting season. This shift in behavior was hypothesized to have occurred due to pigs avoiding typical high-preference habitats used to provide cover and protection from hunters. Hunting has also been documented to cause further temporal changes in their use of habitat, with pigs transitioning to near exclusive nocturnal activity where they bed in thick cover during the daylight hours (Saunders and Kay 1996). Other factors influencing habitat selection include flooding or snowfall, which has been known to cause shifts in elevation, corresponding with restrictions to suitable habitat (Frädrich 1974).

Because wild pigs can thrive in many different environments, their habitat use and selection can vary widely across seasonal changes (VerCauteren *et al*. 2020). The availability of food, water, and cover are key factors in the distribution of wild pigs (McIlroy 1989). During the summer months, wild pigs will prefer habitats with easy access to water sources and their respective habitat types, such as marshes or swamps (VerCauteren *et al*. 2020). During the winter months, flooding and heavy snowfalls can cause pigs to move either up or down in elevation to find more suitable habitat (Frädrich 1974).

Since little or no recreational pig hunting occurs on Network properties, they may provide refugia for pigs that are being hunted on non-Network properties adjacent to or near Network properties. Since heavy snowfall does not occur within the Network, the warmest water-limited months of the summer and early fall may be the most restrictive for wild pig movements. During these times of year, and especially during unusually dry years, artificial sources of water (e.g. water troughs maintained for livestock) may help to sustain wild pigs within areas where they may otherwise not be able to exist.

Regulatory Framework

Within the state of California, pigs have been primarily regulated as a game species, making CDFW the primary managing agency. However, some Network entities have additional responsibilities regarding the regulation of pigs and protection of natural resources within their properties. Relevant regulatory responsibilities and regulations are identified below.

California Department of Fish and Wildlife—Pigs were unclassified by the state of California in Fish and Game Code (FGC) when initially introduced and could be killed without restrictions. However, in 1957, pigs were classified as game mammals under FGC, which identified an annual hunting season, bag limits, and possession limits. In 1992, FGC Sections 4650 through 4657 were established, and hunting tags were required to take pigs (CDFW 2024). Due to growing evidence of damage and conflicts caused by the rapid spread of pigs in California, the hunting season for wild pigs was modified to allow year-round take of pigs, and daily bag limits were removed. However, a tag was still required for each pig removed, and there were restrictions for the methods of take (T14 §708(f); CDFW 2024).

On 17 February 2023, Senate Bill 856 was proposed, subsequently signed by the governor, and provisions of this bill were scheduled to go into effect on July 1, 2024. This bill amended the FGC, which included definitions, licensing, hunting take, captive hunting preserves, capture, possession, and release of pigs. The intent of the bill was to give the public and the CDFW more tools to manage pigs and their damage to private property and the environment. This bill is expected to effect changes that will streamline obtaining and maintaining depredation permits and better support recreational hunting for pigs.

As of the writing of this Plan, CDFW will issue wild pig depredation permits pursuant to the provisions of the California Code of Regulations (CCR), Title 14, section 401. Below is a matrix of the authorities under which pigs may be taken under California law: (1) sport hunting; (2) depredation permit under FGC section 4181 and section 401, CCR, Title 14, section 401; and (3) immediate depredation upon encounter under FGC section 4181.1.

Additional regulations regarding pigs, and management of natural resources by Network entities are provided below:

> Fish and Game CODE – FGC Division 2 1851. (g)
>
> “Habitat enhancement action” means an action to improve the quality of wildlife habitat, or to address risks or stressors to wildlife, that has long-term durability but does not involve land acquisition or the permanent protection of habitat, such as improving in-stream flows to benefit fish species, enhancing habitat connectivity, or invasive species control or eradication.”
>
> Fish and Game Code – FGC Division 4 Part 3 Chapter 7 4651. (a)
>
> “The department shall, upon appropriation by the Legislature for that purpose,

prepare a plan for the management of wild pigs. Under the plan, the status and trend of wild pig populations shall be determined, and management units shall be designated within the state. The plan may establish pig management zones to address regional needs and opportunities. In preparing the plan, the department shall consider available, existing information and literature relative to wild pigs."

California State Parks

"California State Park's resource management policies call for preservation and restoration of native plants and animals and systematic removal of populations of exotics in wildland settings in the State Park System. Using a variety of methods, and often a helping hand from volunteer organizations, the Department strives to protect sensitive species and preserve examples of the unique and diverse ecosystems that make up the rich natural history of this state for present and future generations."

DOM 0303.1.3.1

"The Department and the CDFG signed a general memorandum of understanding that clarifies both departments' general management goals and objectives related to wild pigs. The memorandum acknowledges that wild pigs on State Park System lands adversely impact native plants and animals and that those impacts constitute damage and justify control/removal efforts."

DOM 0311.5.7.2

"A complete and defensible natural resources program, whether in a district, the Natural Resources Division or the Department, should include thoughtful planning, identification of priorities and documentation to ensure protection, management and stewardship of park natural resources."

DOM 0303.1.3.1.1 Planning

a. "Exotic species control: [Each district must] Develop and maintain a written strategy for the removal of priority exotic species from priority areas within the district." -CA DPR Operations Manual, Natural Resources"

DOM 0304.4 Active Management

"Natural resource management is predicated on the understanding that the Department must monitor conditions and take appropriate action to maintain these values. This is accomplished through the combined effort of restoring damaged or altered natural resources and a systematically applied program of regular inspection and maintenance. Efforts may include, for example:

a. Removal of exotic species" -CA DPR Operations Manual, Natural Resources

East Bay Municipal Utility District

BIO.15

"As required by law, control noxious weeds and pest animal species using the most conservative, least toxic, but effective methods available." EBMUD – EBWMP 2018

BIO. 17

"Emphasize control of noxious weeds, invasive plants, and feral animals in or near important wildlife areas, corridors, or other sensitive habitats." EBMUD – EBWMP 2018

BIO 18

"Apply integrated pest management (IPM) strategies, eliminating pesticides where feasible, ensuring negligible impacts on water quality, biodiversity, and other resources and without increasing fire risk." EBMUD – EBWMP 2018

California Department of Food and Agriculture

Food and Agriculture Code – FAC – Division 4 Part 1 Chapter 4.5 (5260)

"The State of California should undertake advance planning on whether and how to address those invasive animals, plants, insects, and plant and animal diseases that are a threat to the state's agriculture, environment, or economy."

SECTION 7: REVIEW OF HISTORICAL NETWORK PIG REMOVAL DATA

Data available from historical pig lethal removal efforts and property specific data, such as sensitive resources present, property boundaries, etc., were requested from the Network. Data were received from nearly all organizations. The CCWD did not submit any data, and only the most recent three years of data from SFPUC were digitized and able to be used for this summary. Data provided were in different formats, with incongruent data fields, and naming conventions. As such, a considerable amount of time was spent organizing data so they could be combined, compared, and evaluated. All pig data collected during the removal efforts were tracked and reported, as required under pig depredation permits, for the duration of the removal activities within Network properties. Depredation permit reports, submitted to CDFW, were not digital during most of the history of pig removal from Network properties and had to be digitized before review. Although some data were able to be digitized, to allow for review during development of this plan, time available within the scope for this effort did not allow for conversion of all records to digital formats.

Digitized data were provided below as an index to how many pigs were within Network properties before and during the time that removals were conducted. The level of pig removal effort throughout the years was described as being fairly consistent; however, no data were available to help evaluate that level of effort. Although pig removal services were provided by the same contractor, these efforts were not conducted by the same personnel for the entire span of the data provided, so methodologies and/or effort may have varied between personnel. Without a metric of effort, trends identified regarding the number of pigs removed may reflect differing removal efforts or methodologies, rather than differences in pig population numbers or geographic distribution. If pig removal effort over time was uniform, the increase in the number of pigs removed since beginning the 1990's suggests that there were more pigs using a Network properties during 2022 and 2023 than during previous years. However, this trend may be specious given the lack of a metric for capture effort.

In total, 13,168 pig removal records were received, reviewed, and compiled. Of those, 41.2% were from the EBRPD, 35.6% were from CA Parks, 20.2% were from the EBMUD and 3% were from the SFPUC (Table 5).

Table 1. Pig removal data received by EBSN partner organizations between 1993 and 2023.

Partner Organization	Pigs Removed
East Bay Regional Park District	5,423
California State Parks	4,690
East Bay Municipal Utility District	2,658
San Francisco Public Utilities Commission	397
Total	**13,168**

Of the pig removal records received, many did not include coordinates to allow for mapping. This was especially prevalent during the early years of pig removal efforts, and understandably so, as GPS units were less common at that time. Many of the older pig removal records did include reference to area names, but area names were not consistent. Additionally, even if naming was similar, since the exact location for traps was unknown, or may have varied during the life of this program, exact locations for those removed pigs cannot be accurately determined. No pig data records containing coordinates were available from some Network partners; therefore, spatial analysis and mapping were not possible for those entities, years, or properties (Table 6).

Table 2. Pig removal data received by EBSN partner organizations, including duration of efforts, number of records, and available coordinates.

Partner Organization	Years of Data	Records	Years with Coordinates	Records with Coordinates
East Bay Regional Park District	2001-2023	5,423	2021-2023	723
California State Parks	2003-2023	4,690	2021-2023	529
East Bay Municipal Utility District (EBMUD)	1993-2023	2,658	N/A	0
San Francisco Public Utilities Commission (SFPUC)	2021-2023	397	2021-2023	397
Contra Costa Water District (CCWD)	N/A	N/A	N/A	N/A

Pig removal data span 1993 to 2023, although data from 2023 did not include all months for that year due to the timing of initiating data review for this plan. Removal data indicate that only EBMUD was removing pigs between 1993 and 2001. Only two California State Parks exist within the Network, Mt. Diablo and Carnegie State Vehicular Recreation Area. Pig removal data for those properties began in 2002, but not all removal data from Carnegie SVRA were consistently recorded. Pig removal data provided from Network partners, indicated a general increase in the number of pigs removed across all Network partner organizations between 1993 and 2023 (Table 7, Fig. 2).

Table 3. Yearly pig removal data received by EBSN partner organizations.

Year	CA Parks	EBMUD	EBRPD	SFPUC	Total
1993		29			29
1995		18			18
1996		20			20
1997		31			31
1998		60			60
1999		47			47
2000		48			48
2001		51	165		216
2002		58	77		135

Year	CA Parks	EBMUD	EBRPD	SFPUC	Total
2003	73	49	168		290
2004	90	101	93		284
2005	157	117	151		425
2006	169	108	367		644
2007	163	109	220		492
2008	53	139	135		327
2009	180	93	160		433
2010	163	95	208		466
2011	117	30	94		241
2012	254	51	327		632
2013	146	49	175		370
2014	394	36	124		554
2015	158	27	160		345
2016	251	39	195		485
2017	382	36	275		693
2018	418	110	197		725
2019	353	145	358		856
2020	487	146	739		1,372
2021	306	219	434	110	1,069
2022	262	355	193	163	973
2023	114	242	408	124	888
Total	**4,690**	**2,658**	**5,423**	**397**	**13,168**

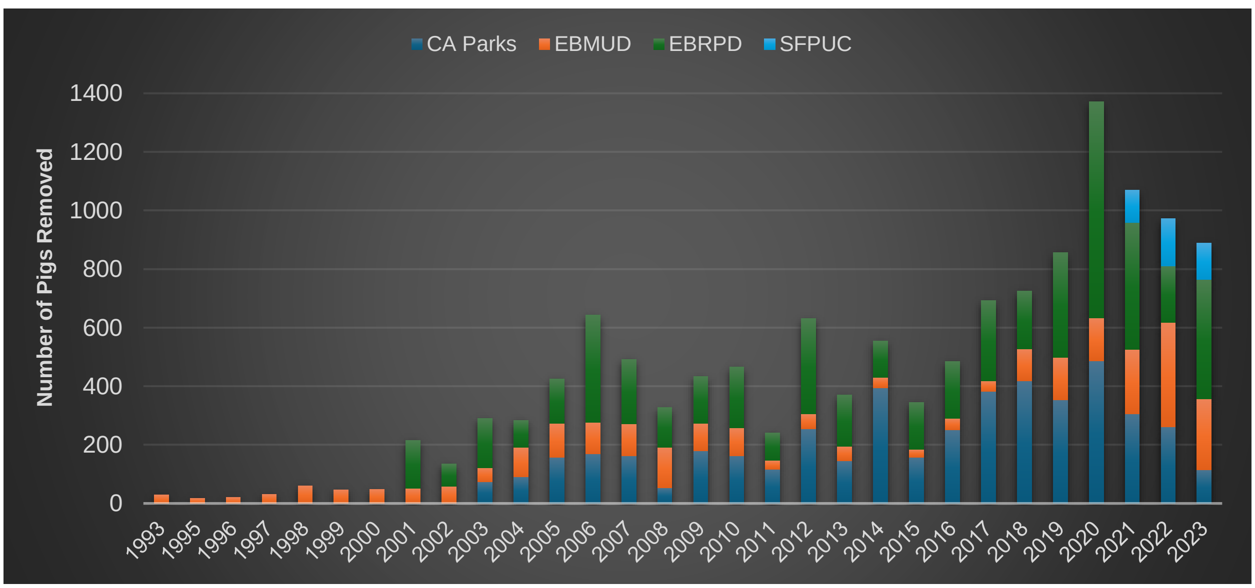

Figure 2. Yearly pig removals from EBSN properties between 1993 and 2023. Note: Data from 2023 does not include all months.

When pigs removed for all years were combined and graphed by month, the number of pigs removed by month seems to have been relatively consistent (Fig. 3). This consistency may have more to do with the capacity of effort available for pig removal personnel, weather-related constraints, or hours across partner organization projects, than the number of pigs present on the landscape.

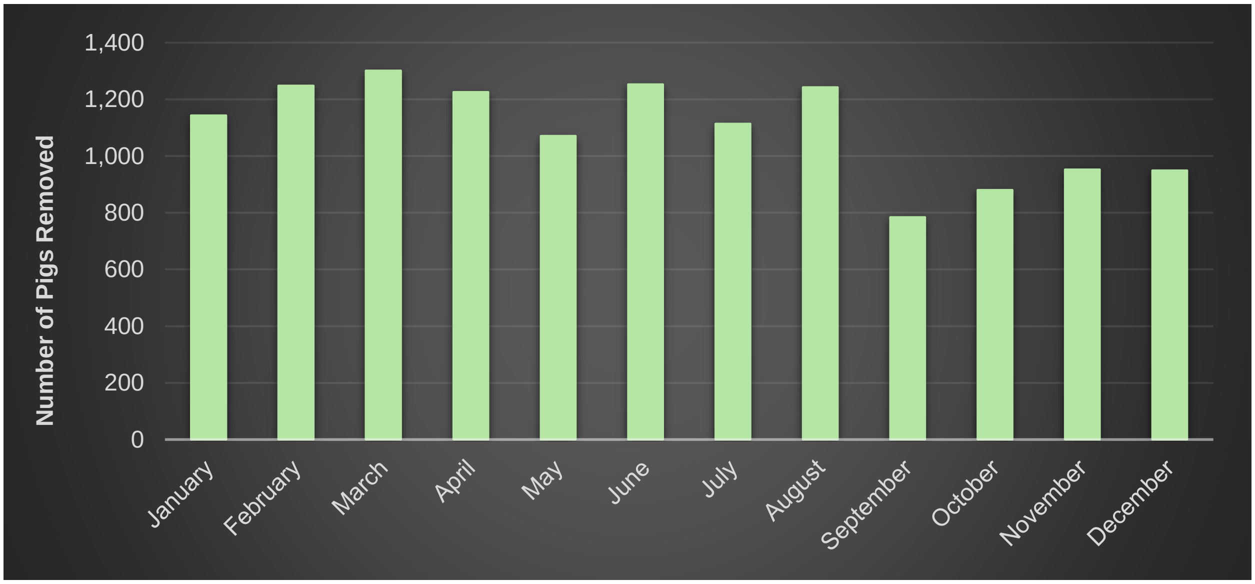

Figure 3. Monthly pig removals from all EBSN properties between 1993 and 2023.

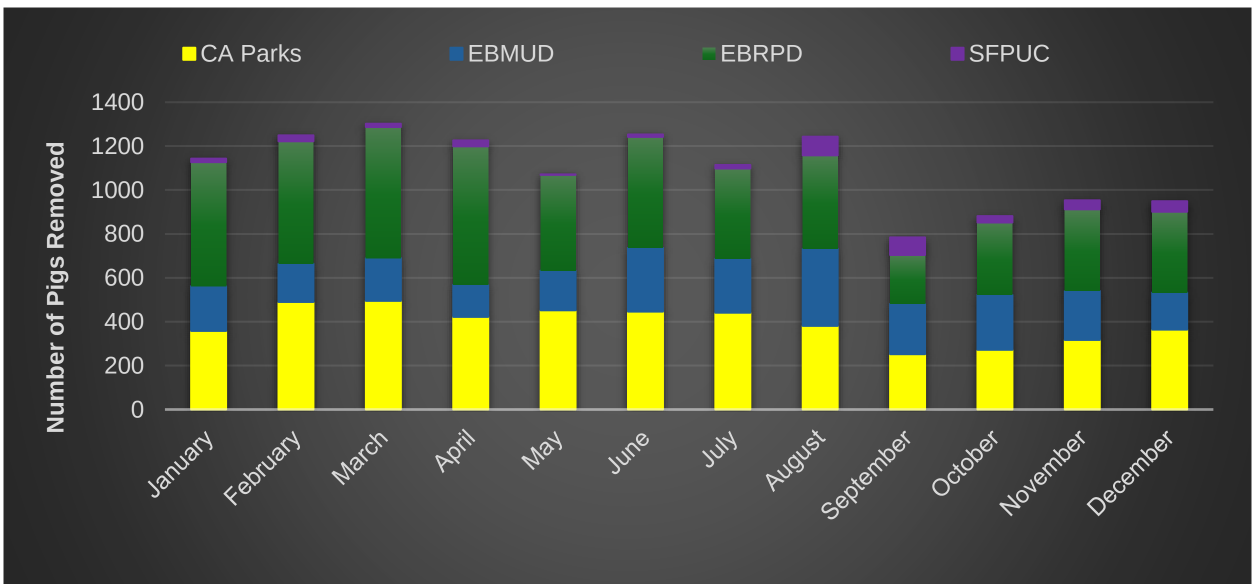

Figure 4. Monthly pig removals from EBSN properties by partner organization between 2018 and 2023.

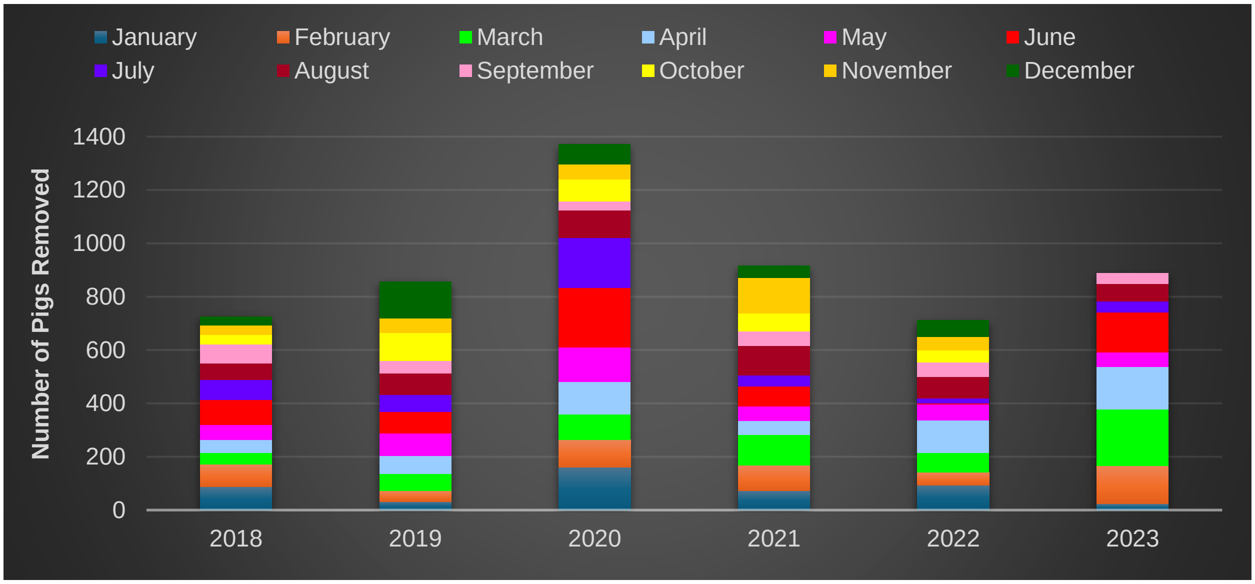

Figure 5. Monthly pig removals from EBSN properties between 2018 and 2023.

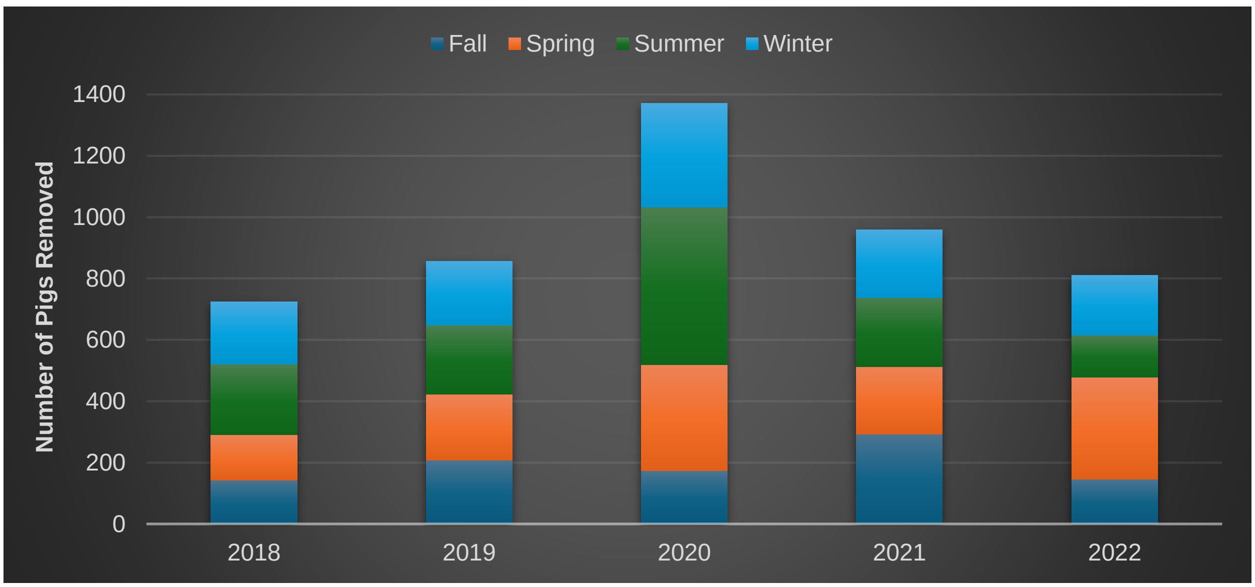

Figure 6. Pig removals between 2018 and 2022 by season. Seasons were defined as Fall (September-November), Winter (December-February), Spring (March-May), and Summer (June-August).

Table 4. Monthly pig removal data by EBSN partner organizations.

Month	CA Parks	EBMUD	EBRPD	SFPUC	Total
January	358	204	565	16	1,143
February	490	174	558	27	1,249
March	495	195	597	15	1,302
April	422	146	631	27	1,226
May	452	181	436	2	1,071
June	446	290	506	11	1,253

Month	CA Parks	EBMUD	EBRPD	SFPUC	Total
July	441	246	411	16	1,114
August	381	351	426	85	1,243
September	252	229	223	80	784
October	272	250	330	29	881
November	317	223	372	41	953
December	364	169	368	48	949
Total	**4,690**	**2,658**	**5,423**	**397**	**13,168**

Data were not available for all entities for all years. Therefore, only the data from the longest standing pig programs at partner organization properties were used. Those were EBRPD, EBMUD, and CA Parks. Data were grouped into five-year groups and averaged, then graphed. The trend indicates a large increase in pig removals during the most recent five-year period (Fig. 7).

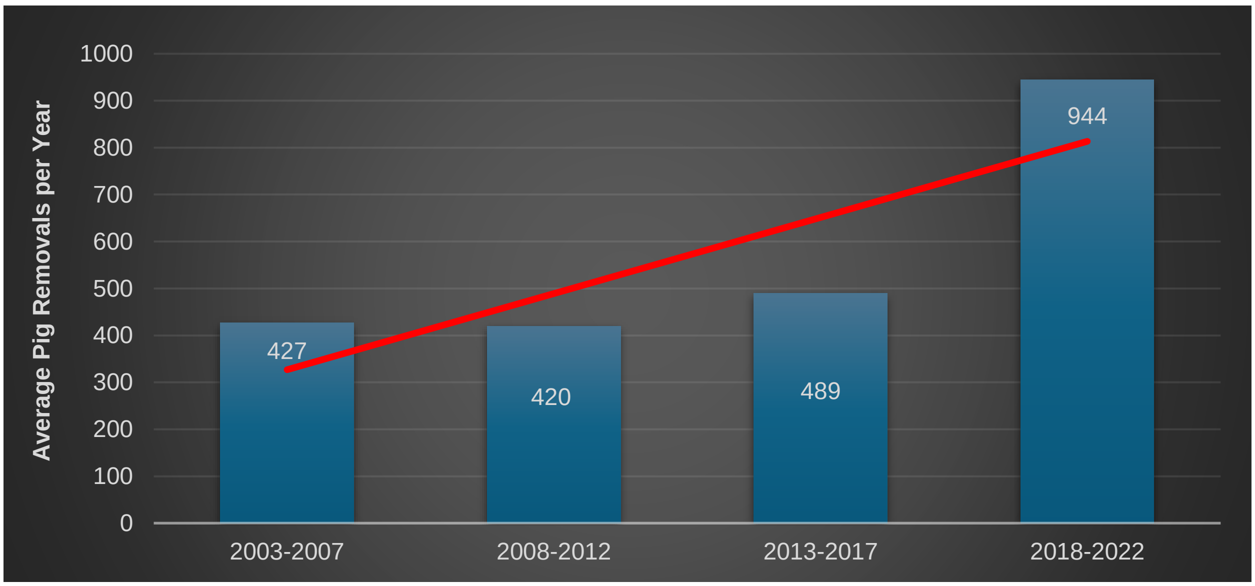

Figure 7. Average number of pig removals from EBRPD, EBMUD, and CA Parks between 2003 and 2022 broken down into five-year intervals. Note: Data for SFPUC was not included, since only a few years of data were available. Data from CCWD not available.

Pig Removal Data by Partner Organization

Pig removal data, available from EBSN partner organizations, provided information regarding where pigs were removed from within Network properties. The data collected only reflects trapping and removal efforts, which means that the absence of recorded removals from certain areas does not necessarily indicate that pigs are not present there. Pig removals typically occurred when the pig contractor detected signs or damage along roadways or when land managers reported pig observations or damage. However, relying solely on these reports without comprehensive monitoring could lead to gaps in understanding the true extent of pig activity across the area. To accurately assess pig presence, surveillance and monitoring efforts will be necessary.

East Bay Regional Park District—Pigs have been removed from 18 different properties, owned and managed by the EBRPD (Fig. 8–10). Pig removal data records began in 2001, with a total of 5,423 total pig removal records provided. For population evaluation and growth projections, EBRPD properties that were in the same general area, with likely the same pigs, were combined. Five areas where 96% of removals were recorded were identified as the most prominent, due to pig removals and geographic distribution. Of the pigs removed from EBRPD properties since 2001, 47% were removed from Morgan Territory (n=2,442), 12% from Bishop Ranch/Dublin Hills (n=612), 12% from Black Diamond Mines (n=616), 10% from Las Trampas (n=517), and 9% were removed from Garin (n=475).

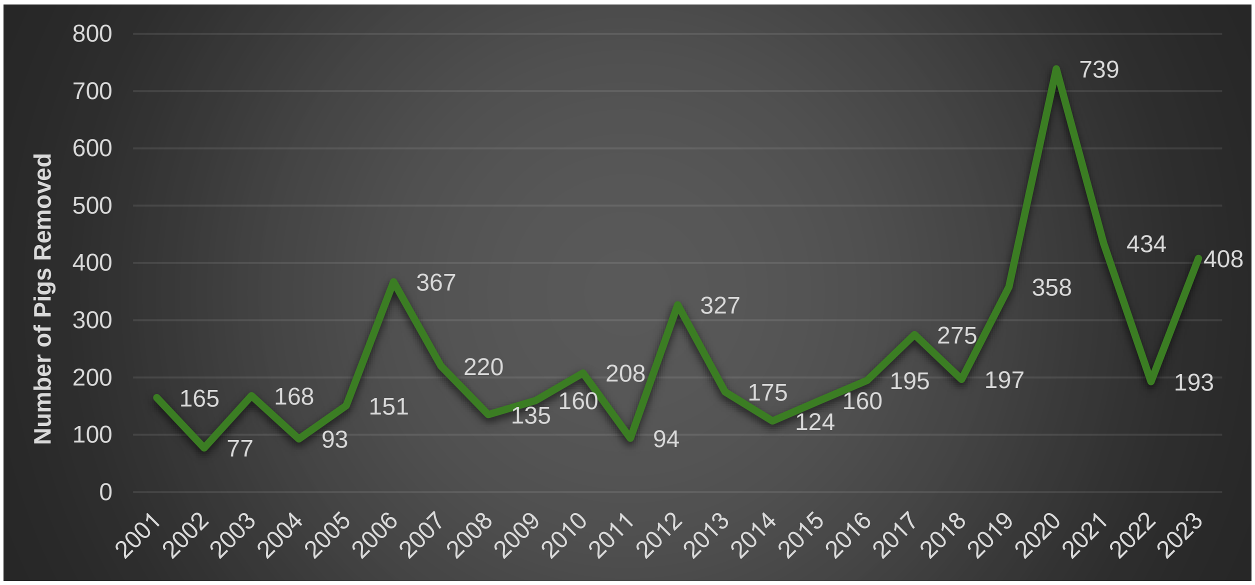

Figure 8. Combined yearly pig removals from five EBRPD properties between 2003 and 2023. Note: Data from 2023 do not include all months.

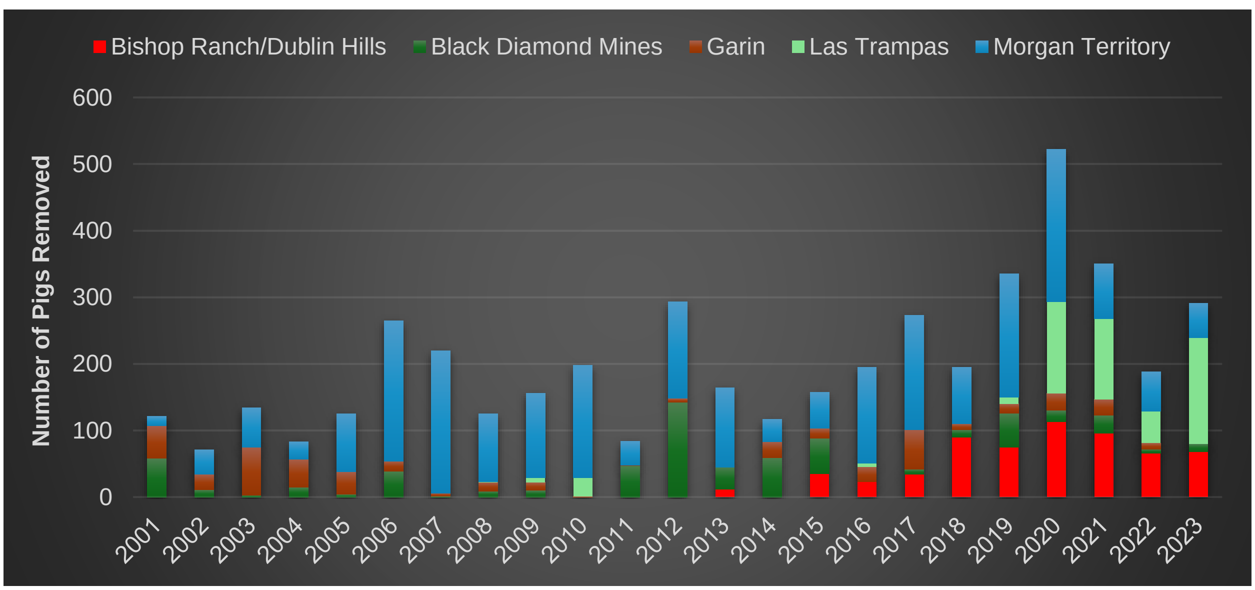

Figure 9. Yearly pig removals from five EBRPD properties between 2003 and 2023. Note: Data from 2023 do not include all months. Note: Data was not available for all months during 2023.

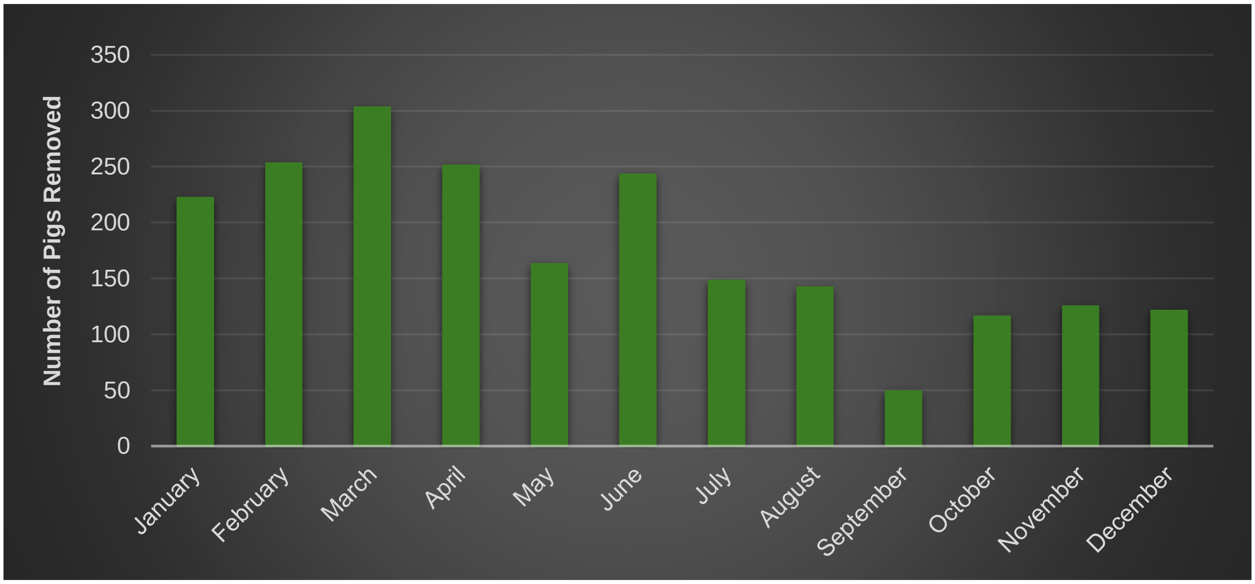

Figure 10. Combined monthly pig removals from five EBRPD properties between 2018 and 2023. Note: Data was not available for all months during 2023.

During the last six years, pigs have been removed from 36 properties or property areas (Table 9). The properties that had the greatest number of pigs removed were Morgan Territory Regional Preserve (25%), Dublin Hills Regional Park (15%), and Las Trampas (7%). Between 2018 and 2023, the property name was not recorded for 10% (n=231) of pigs removed.

Table 5. Pigs removed from EBRPD properties between 2018 and 2023.

Property	2018	2019	2020	2021	2022	2023	Total
Morgan Territory Regional Preserve	85	185	229	84			583
Dublin Hills Regional Park	90	75	121	61			347
Property Not Recorded		22	124	71		14	231
Las Trampas					48	110	158
Las Trampas Regional Park				92			92
Las Trampas Wilderness Regional Preserve		8	61	22			91
Cull Canyon						89	89
Black Diamond Mines Regional Preserve	11	47	17	13			88
Little Hills Regional Recreation Area		2	76	7			85
Morgan Territory					59	18	77
Garin Regional Park	9	14	26	24			73
Weidemann property					66		66
Dublin Hills						63	63
Cull Canyon Regional Recreation Area			39				39
Sunol Regional Wilderness				30			30
Las Trampas Area						27	27
Redwood Canyon Golf Course			17	9		1	27
Morgan Territory Area						20	20
Las Trampas Chen Property						18	18
Anthony Chabot					5	12	17
Black Diamond					5	12	17
Anthony Chabot Regional Park			15	1			16
Pleasanton Ridge						12	12
Black Diamond Mines Regional Park				11			11
Lake Chabot Regional Park			10				10
Redwood						9	9
Clayton Ranch Regional Preserve		4		3			7
Garin					7		7
Contra Loma Regional Park	2		3	1			6
Ohlone Regional Wilderness				4			4
Castle Rock		1	1				2
Garin Park					2		2
Redwood Regional						2	2
Alamo Crest						1	1
Clayton					1		1
Roddy Ranch Golf Course				1			1
Total	**197**	**358**	**739**	**434**	**193**	**408**	**2,329**

California State Parks—Mount Diablo State Park (MDSP) and Carnegie State Vehicular Recreation Area are the only California State Park properties within the Network. During the history of pig removal efforts within available data, only two pigs have been recorded for Carnegie SVRA, which occurred during 2020. Therefore, only pig removals from MDSP were summarized herein and used to create future pig population projections for MDSP. Pig removal data for MDSP began in 2003, and in total, 4,690 pigs have been removed from that property. Although the number of pigs removed annually fluctuated, the number of pigs removed generally increased between 2003 (n=73), and 2022 (n=262; Fig.11). Pig removals fluctuated considerably between 2011 and 2015, with multiple highs and lows recorded. Following a lower year during 2015, the number of pigs removed generally increased until a high in 2020 (n=487), which was the highest year on record. Pig removals peaked in March, and again in June, but were lower July through December (Fig. 12–13).

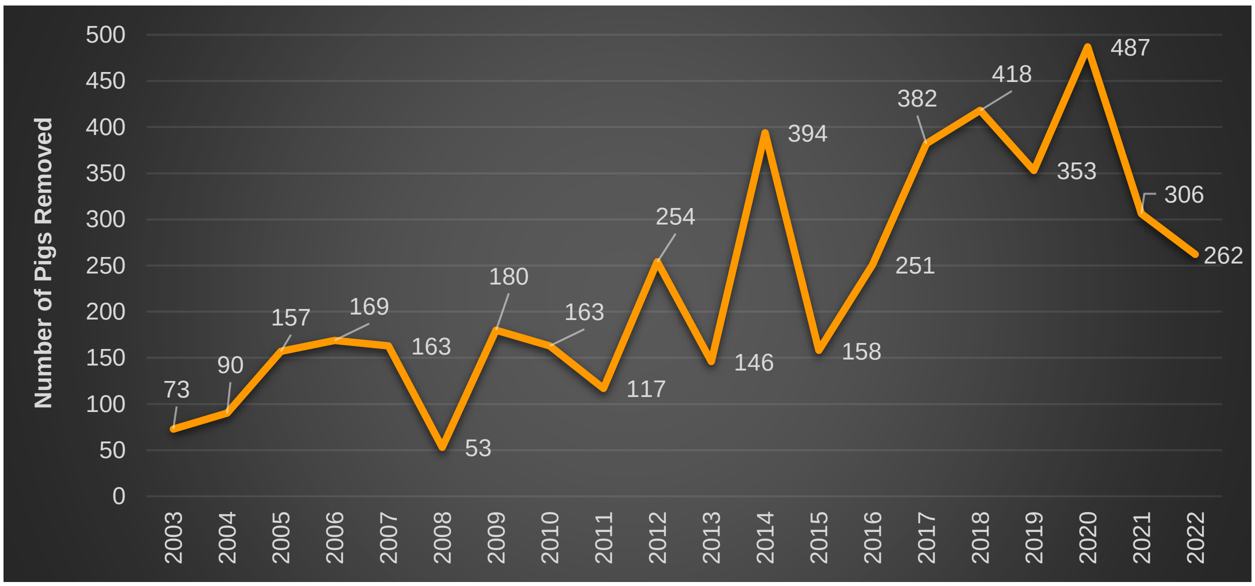

Figure 11. Yearly pig removals from Mt. Diablo State Park between 2003 and 2022.

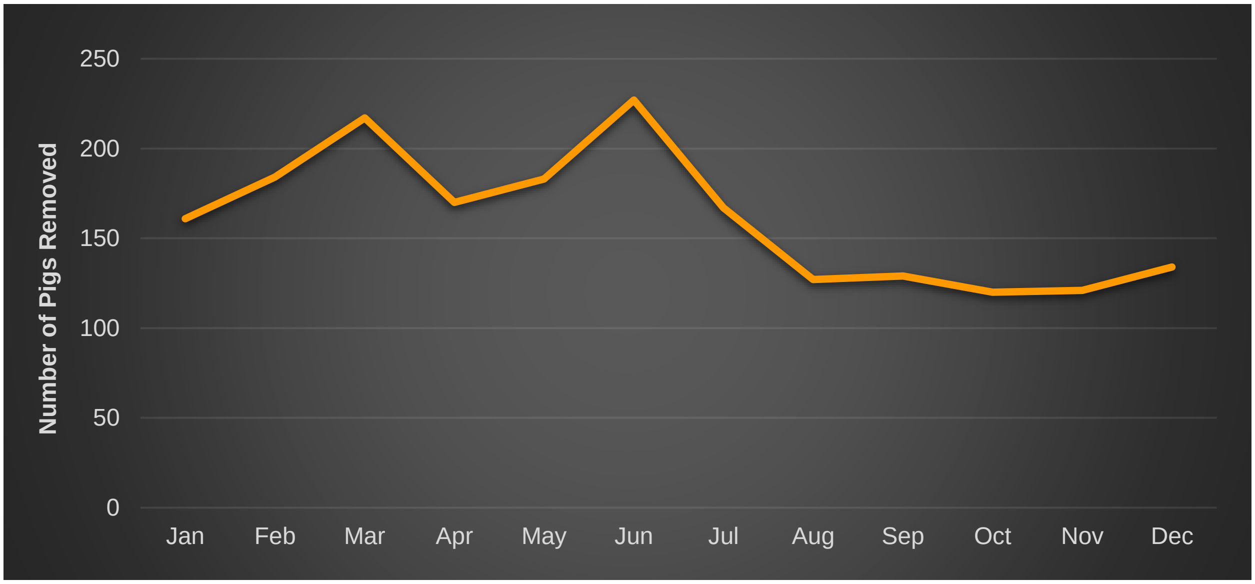

Figure 12. Total monthly pig removals from Mt. Diablo State Park between 2018 and 2023. Note: Data was not available for all months during 2023.

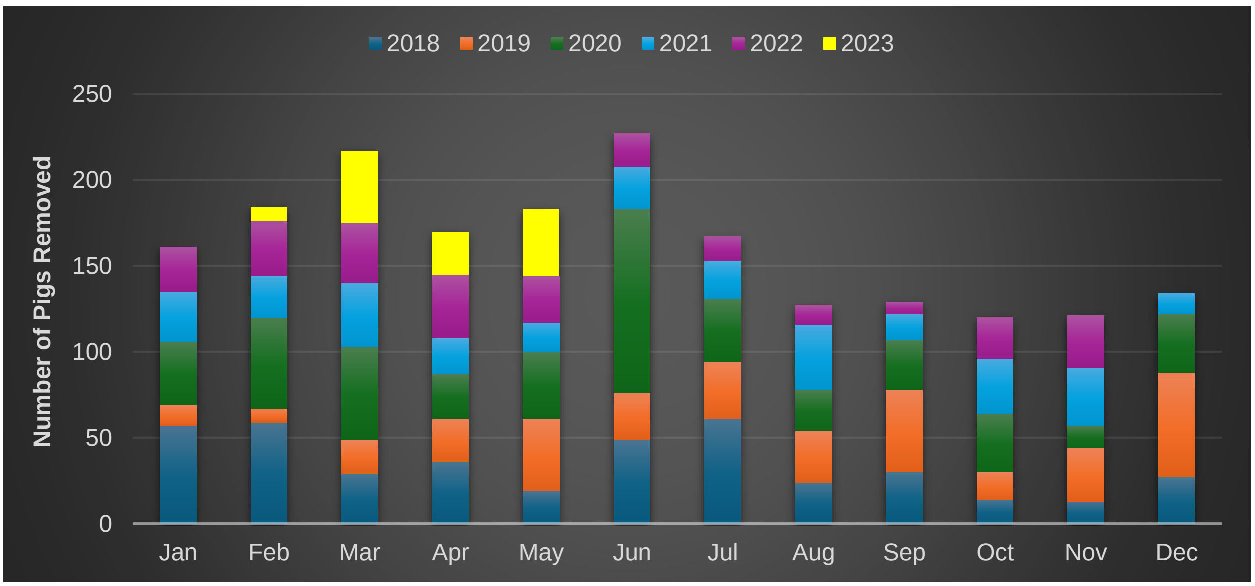

Figure 13. Monthly pig removals from Mt. Diablo by year between 2018 and 2023. Note: Data from 2023 do not include all months. Note: Data was not available for all months during 2023.

East Bay Municipal Utility District—Pig removal efforts have only occurred in the Upper San Leandro Reservoir watershed. The number of pigs removed increased substantially between 2017 and 2022 (Fig. 14). If pig removal effort was fairly consistent over the entire period, pigs seem to be increasing in number on these lands.

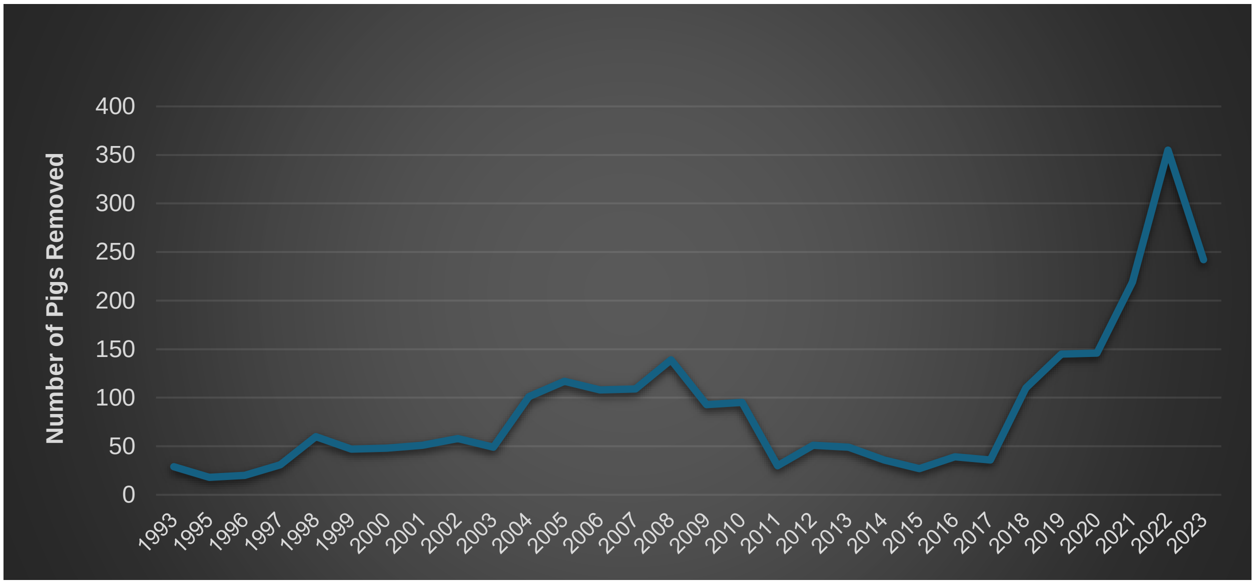

Figure 14. Yearly pig removals from East Bay Municipal Utility District properties between 2003 and 2023. Note: Data was not available for all months during 2023.

Cumulative data indicate that more pigs are removed from the EBMUD Upper San Leandro Reservoir watershed during the summer (May–August; Fig. 15), which is the time of year that fewer pigs are typically removed from other Network partner organization properties.

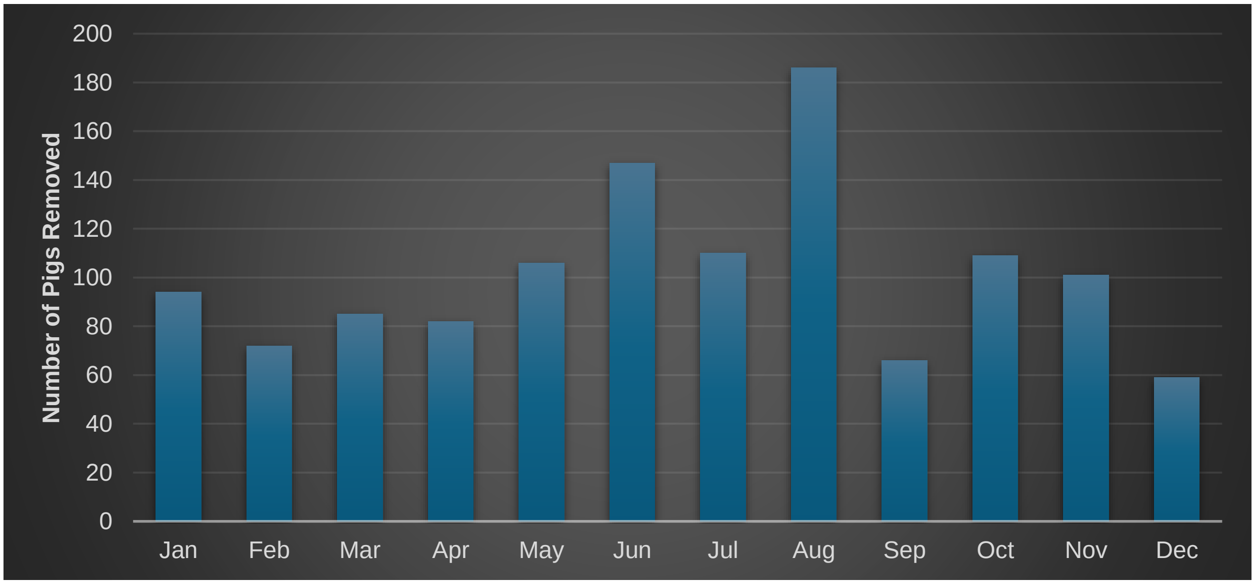

Figure 15. Monthly pig removals from the East Bay Municipal Utility District Upper San Leandro Reservoir watershed between 2018 and 2023. Note: Data was not available for all months during 2023.

Pig removal data available for EBMUD's Upper San Leandro Reservoir watershed were graphed using the trapping location name provided; Rifle Range Road and Miller Road are the locations where the greatest number of pigs were removed (Fig. 16). Reviewing pig removals by trapping location and month indicates that more pigs have been removed from Rifle Range Road during

June, from Kaiser Flat during December, from Rocky Ridge during November, and from Boat Ramp Road during March (Fig. 16).

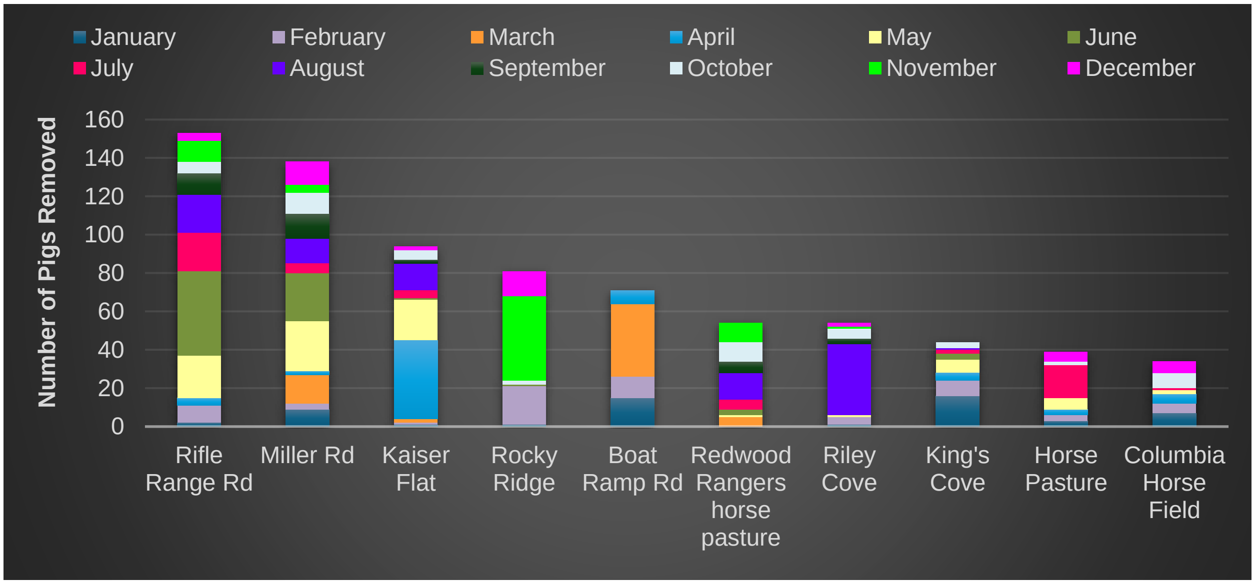

Figure 16. Monthly pig removals from the top ten locations within the East Bay Municipal District Upper San Leandro Reservoir watershed between 2018 and 2023. Data was not available for all months during 2023.

Pig removal data graphed by trapping location during the last six years indicate that during 2023 more pigs were removed from Rifle Range Road than anywhere else, although some pigs were removed from six more locations (Fig. 17). During 2022, more pigs were removed from Kaiser Flat than anywhere else but was closely followed by Rifle Range Road, Miller Road, Rocky Ridge, Boat Ramp Road, and Redwood Rangers Horse. During 2021, Rocky Ridge and Boat Ramp Road were hotspots for pig removals, with Miller Road substantially leading the number of removals during 2020.

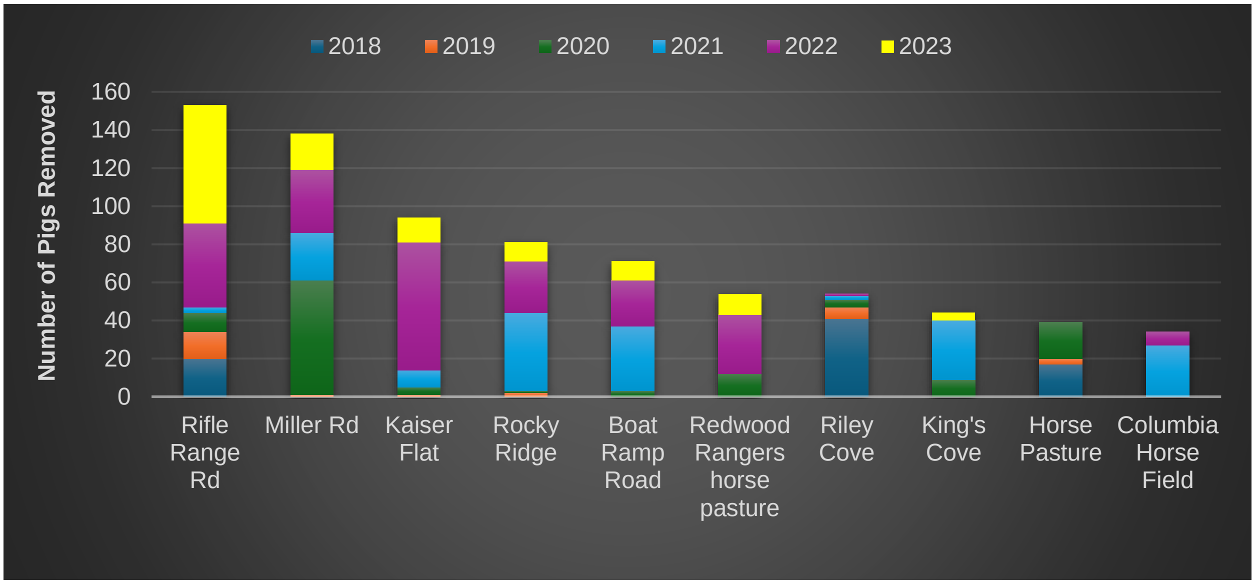

Figure 17. Pig removals by month, from the top ten locations within the East Bay Municipal District Upper San Leandro Reservoir watershed, between 2018 and 2023. Note: Data was not available for all months during 2023.

San Francisco Public Utilities Commission—The SFPUC provided three years of useable digitized data for this effort, totaling 397 pig removal records. Data included records from Calaveras Reservoir, the San Antonio Reservoir, and the Sunol Wilderness. Based on those data, more pigs were removed during 2022 than in other years (Fig. 18). Pig removal data indicate that, like EBMUD, more pigs were removed from SFPUC properties during the summer months. Assuming that pig removal effort is relatively constant, or that pig removals were conducted following reported observations of pigs or damage, more pigs are using SFPUC properties during July, August, and September than during other months (Fig. 19). By graphing SFPUC pig removal data by month and by year, data indicate that all pigs were removed between July and December during 2021. Conversely, pig removals during 2022 were spread across all months, with more removed during November and December than other months. During 2023, more pigs were removed during August and September than during other months, although data were incomplete for that year (Fig. 19).

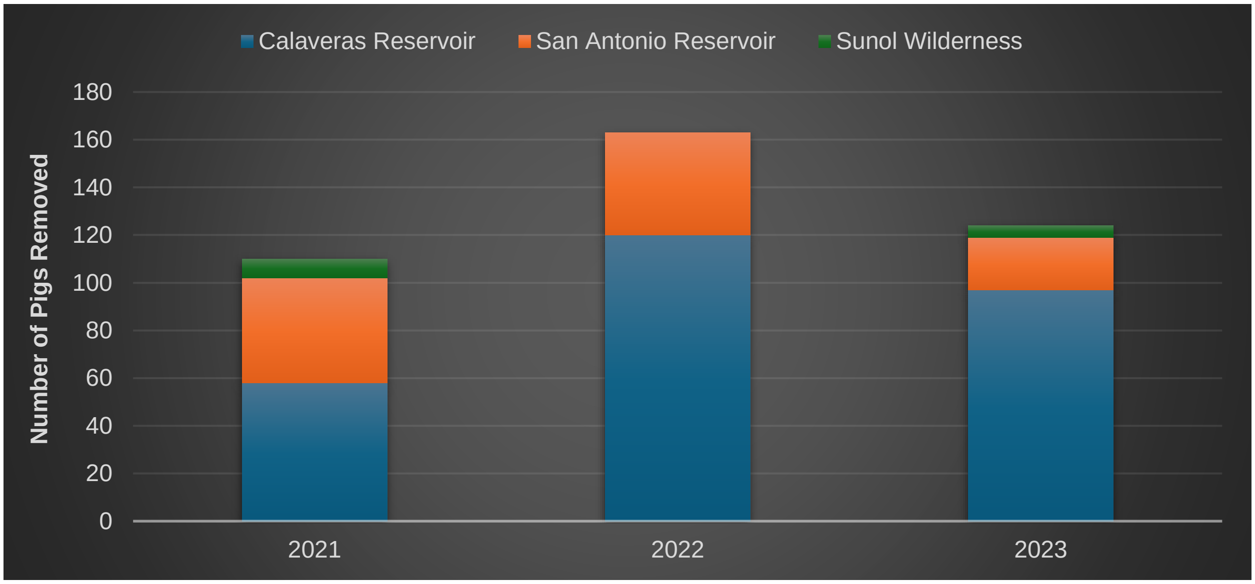

Figure 18. Pig removals by year and property, from San Francisco Public Utilities Commission properties, between 2021 and 2023. Note: Data from 2023 were incomplete.

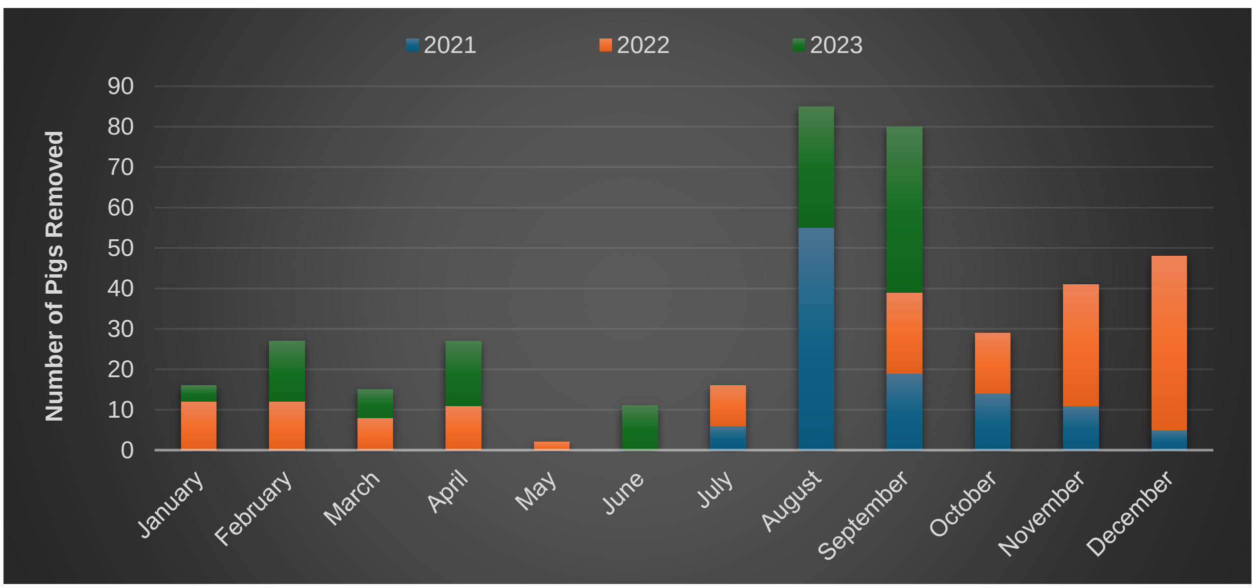

Figure 19. Pig removals by month and year, from San Francisco Public Utilities Commission properties, between 2021 and 2023. Note: Data from 2023 were incomplete.

Contra Costa Water District—No pig removal or other data were provided by CCWD; therefore, no data evaluation or summaries were possible.

Public Data

To try to better understand pig presence outside of, but near, Network properties, two Public Records Act requests were submitted to CDFW. Data from public observations of pigs were also downloaded from iNaturalist for years 2016–2022 (few records exist within iNaturalist before that).

With support from CDFW, data from the Wildlife Incident Reporting (WIR) system and data for hunter take of wild pigs from properties near Network properties (generally located within Alameda and Contra Costa Counties) were acquired from 2017–2022. Data from the WIR system included pigs removed through depredation permits and reported incidents of pig damage, sightings, and potential human safety. In some cases, WIR records may have included records for incidents that occurred within Network properties, but based on data comparisons, few or none of the depredations reported from network properties were included within the dataset received from the WIR system. All public data records were considered evidence of pig presence during the timeframe and within the geographic areas they were reported to have occurred within. Both data types included location coordinates for each pig reported or removed. The CDFW cautioned that the locations of hunter removed pigs had not been reviewed for accuracy, and this could also be true for location information provided for data records from the WIR system. Furthermore, they warned that the coordinates for data points could be inaccurate for either data source for a variety of intentional and unintentional reasons. Since the approximate location of pigs observed or removed was sufficient to identify and evaluate clusters of pig points indicating pig presence, the locations reported were used as they were received and these data reviewed, compiled, and mapped by WI. Mapped data were reviewed for clusters of pig presence near Network properties that may indicate potential sources of immigration and population refill following removal of pigs from within Network properties. Clusters of hunter-removed pigs from private properties, near Network properties, may indicate the presence of a professional guided hunting operation. If hunts are being sold by professional guides on properties adjacent or near Network properties, land management practices on those private properties may be conducted to promote the presence of pigs and conflict with the management of pigs on Network properties.

In total, 922 records of pig presence were obtained, reviewed, and mapped from those public data sources (Table 10). Of those, 54% were from the WIR System, 30% were Recreational Hunting, and 15% were from iNaturalist. A majority of pig presence points from those data sources were located within the East Bay Hills Middle LU (53%), followed by the Mt. Diablo LU (30%) and the Mt. Hamilton LU (12%). The geographic distribution in these public data was similar to pig removal data from Network properties across the LUs.

Table 6. Data from iNaturalist, the Wildlife Incident Reporting System, and CDFW recreational hunter removal data.

Landscape Unit	iNaturalist	Recreational Hunting	Wildlife Incident Reporting System	Total
East Bay Hills North	5		2	7
East Bay Hills Middle	47	196	249	492
East Bay Hills South	9	6	19	34
Mt. Diablo	67	21	187	275
Mt. Hamilton	12	62	40	114
Total	**140**	**285**	**497**	**922**

Publicly sourced pig presence data included records from 2016-2022, with the fewest records obtained for 2016 (Fig. 20). The number of pig records fluctuated during that time, with the greatest number of records available for 2018 and 2019. East Bay Hills LU produced the greatest number of records during all years, with the East Bay Hills South LU only reported pig presence during three of the seven years.

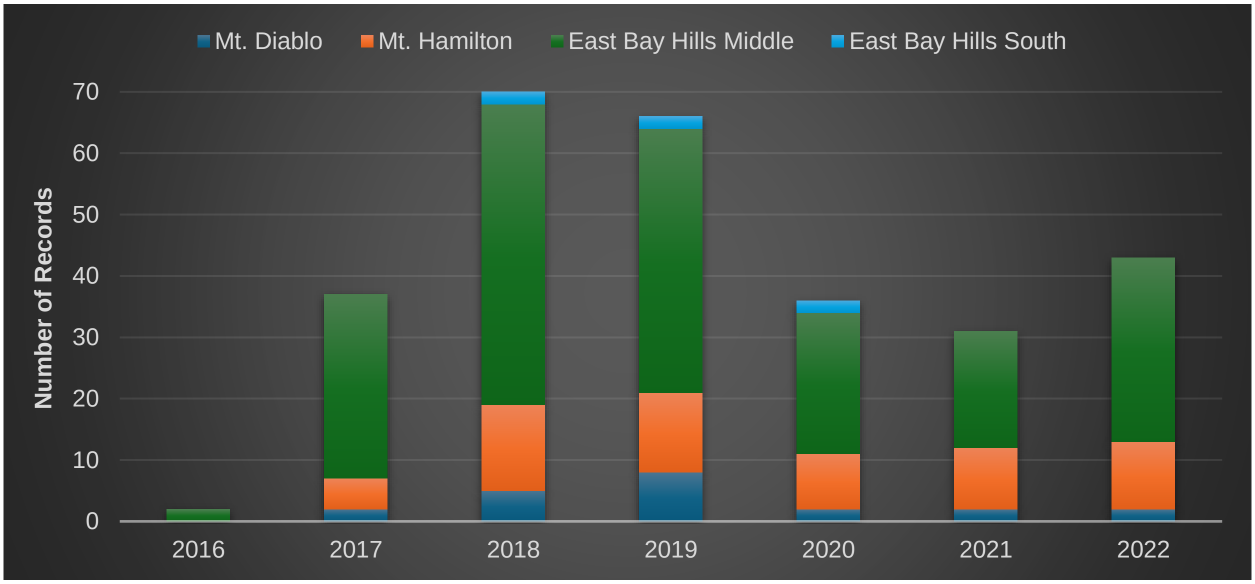

Figure 20. Data received from Wildlife Incident Reporting System and recreational hunter removal data, provided by CDFW and iNaturalist, by Landscape Unit and year.

Public data records obtained included all months when summed across years, although the number of records for each data type fluctuated across the months of the year (Fig. 21). Recreational hunting records didn't appear to be seasonally dependent, although more pigs were removed via recreational hunting during February (11%), April (11%), May (14%), August (11%) and September (13%) than during the other months. More WIR records occurred during the summer and fall, with the highest numbers in August (13%), September (17%), October (17%), and November (11%).

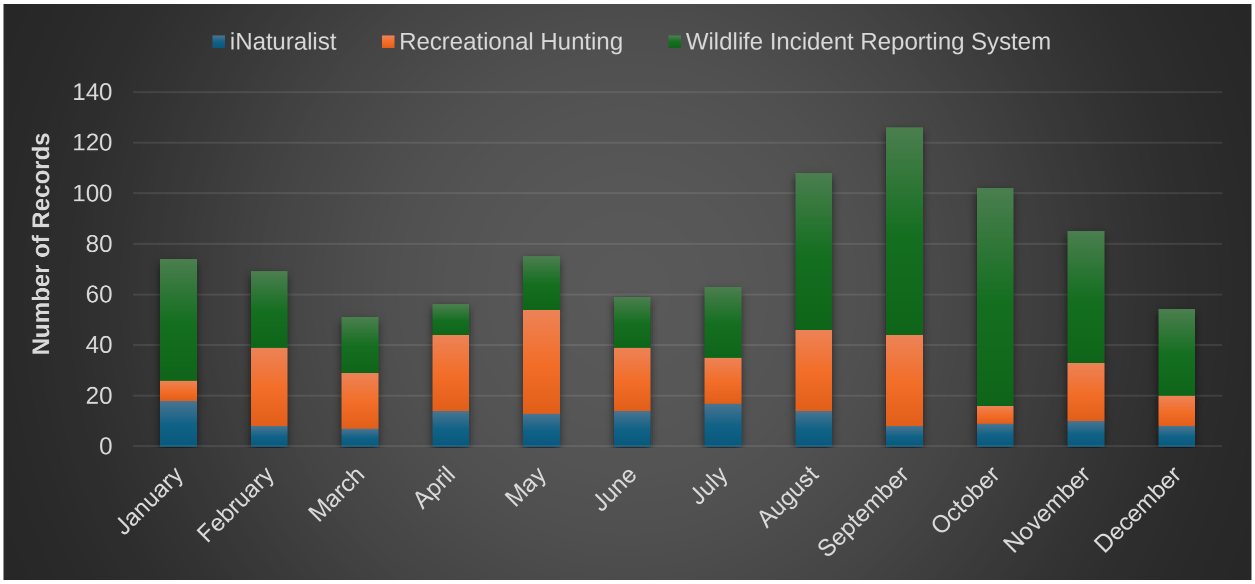

Figure 21. Data from iNaturalist and CDFW's Wildlife Incident Reporting System and recreational hunter

removals by source and month.

<u>Population-level Analysis of Past, Present, and Projected Wild Pig Populations</u>

Population growth and density are important metrics to understand population dynamics and reproductive success of pigs; however, limited studies have been performed in only a few locations in the U.S. (Snow *et al*. 2020). Understanding the population dynamics of pigs in a particular location can inform the amount of targeted removal required to reduce their populations and determine the success of management actions (Snow *et al*. 2020).

An accurate population growth estimate requires knowledge of a population's sex ratio, age structure, survival, reproduction, and mortality, by age class and litter sizes (Snow *et al*. 2020). Some of this information can be estimated using data available from literature; however, few California-specific data are available. A more simplified estimation of population growth can be determined using only birth and death rates (Snow *et al*. 2020) obtained via mark-recapture methods (i.e., trapping, tagging, and then resighting individuals with trail cameras; Sweitzer *et al*. 2000).

In the absence of habitat constraints, due to their rapid ability to reproduce, populations of pigs can triple every year (Waithman 2001). In addition, studies performed on pigs in the U.S. have estimated that annual removal rates required for pig population reduction can be as low as 20% and as high as nearly 70%, depending on the specific pig population. Due to this variability, it is crucial to understand the population dynamics for the location where population management is desired (Snow *et al*. 2020).

Not all the pig removal data received from EBSN partners included age, sex, and removal locations, and the sex and age data were not collected by following guides or protocols. Since trapping effort can skew the probability of pig detections (Schlichting *et al*. 2020), and no trapping effort data are available for this study area, using that information to estimate a total population is not possible. However, population sampling, using camera trap data, can be used to determine the necessity for and efficacy of management programs. Initiating a well-designed camera trap study can provide data for determining the population growth rate in a particular location.

Since none of the data previously noted as required to accurately assess population growth at Network properties were available, it was not possible to calculate an accurate population estimate, and population growth rate. In order to provide a visual display of differing percentages of population reduction, we utilized a 32% population growth estimate from a pig population in Texas (Snow et al. 2020). This population growth rate may not be reflective of the population of pigs within Network properties, and was only used to provide examples of how growth rate and different levels of pig removal affect the number of pigs on the landscape. Note, the projections below were obtained using the available data for Network and adjacent lands and projected using a growth rate from a pig population in Texas, which may not accurately reflect population growth within Network properties.

Due to the lack of information about the overall population size, we assumed that the number of pigs removed from each property represented a minimum number of pigs that existed within each area. We then applied the 32% population growth rate to that minimum number of pigs, along with varying rates of removal, to determine the impacts on hypothetical pig populations for target properties. Using this very simplified method, we determined that anything greater than a 24% annual removal rate would reduce pig populations year over year, for this hypothetical population with a growth rate of 32%. Due to data constraints, we were unable to determine the impacts that annual variation in removal rates would have on pig populations within Network properties.

The following population calculations were made using data referenced above which were provided by the property owner, and only for representative properties for which enough data existed to support these calculations. Since data from 2022 were nontypical and data from 2023 were incomplete, population modeling calculations were conducted using pig removal data from 2021, for all properties.

East Bay Regional Park District Population Analysis— Using the number of pigs removed during 2021, and an example population growth rate of 32%, the following population projections were derived for consideration (Table 11–13, Fig. 22–24). Since the generic growth rate applied was 32%, it is not surprising that a removal effort of greater than 32% per year is necessary to prevent population growth, and that when 40% and 60% of the pigs within a property are removed, the population is reduced more quickly. Although data were provided for multiple properties within some regions (e.g., Las Trampas), the data were summed for the region. Pigs are mobile, and properties are not fenced to prevent movement of pigs. Therefore, pigs that use one property are likely to move between properties within the same region. Example projections were only provided for Morgan Territory, Las Trampas, and Garin, as additional projections would be similar and would not likely add benefit.

Table 7. Population growth modeling for Morgan Territory with different levels of pig removal.

Year	0%	20%	40%	60%
2021	82	82	82	82
2022	108	87	65	43
2023	143	91	51	23
2024	189	97	41	12
2025	249	102	32	6
2026	329	108	26	3
2027	434	114	20	2
2028	573	120	16	1
2029	756	127	13	0
2030	998	134	10	0

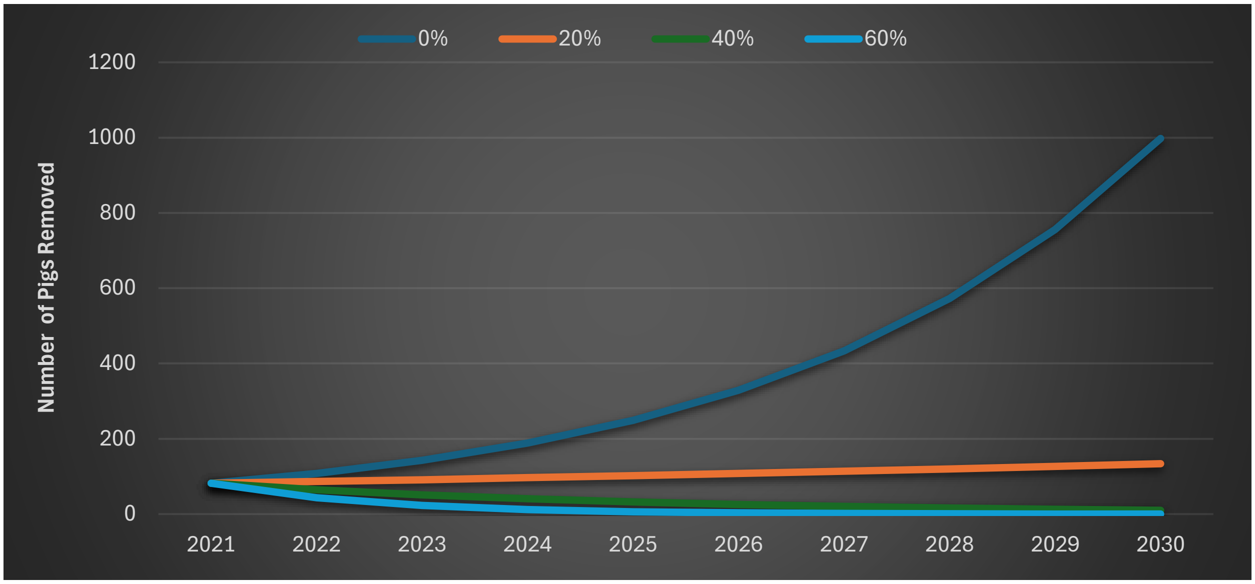

Figure 22. Yearly population growth modeling for Morgan Territory with different levels of pig removal.

Table 8. Yearly population growth modeling for Las Trampas with different levels of pig removal.

Year	0%	20%	40%	60%
2021	121	121	121	121
2022	160	128	96	64
2023	211	135	76	34
2024	278	142	60	18
2025	367	150	48	9
2026	485	159	38	5
2027	640	168	30	3
2028	845	177	24	1
2029	1115	187	19	1
2030	1472	198	15	0

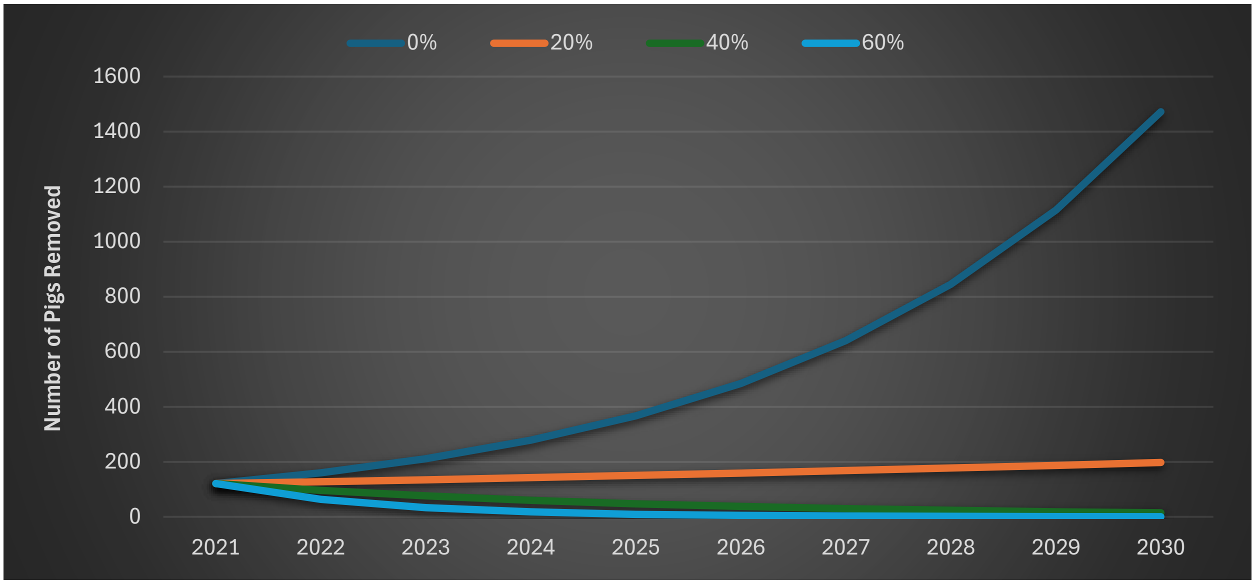

Figure 23. Yearly population growth modeling for Las Trampas with different levels of pig removal.

Table 9. Yearly population growth modeling for Garin with different levels of pig removal.

Year	0%	20%	40%	60%
2021	24	24	24	24
2022	32	25	19	13
2023	42	27	15	7
2024	55	28	12	4
2025	73	30	9	2
2026	96	32	7	1
2027	127	33	6	1
2028	168	35	5	0
2029	221	37	4	0
2030	292	39	3	0

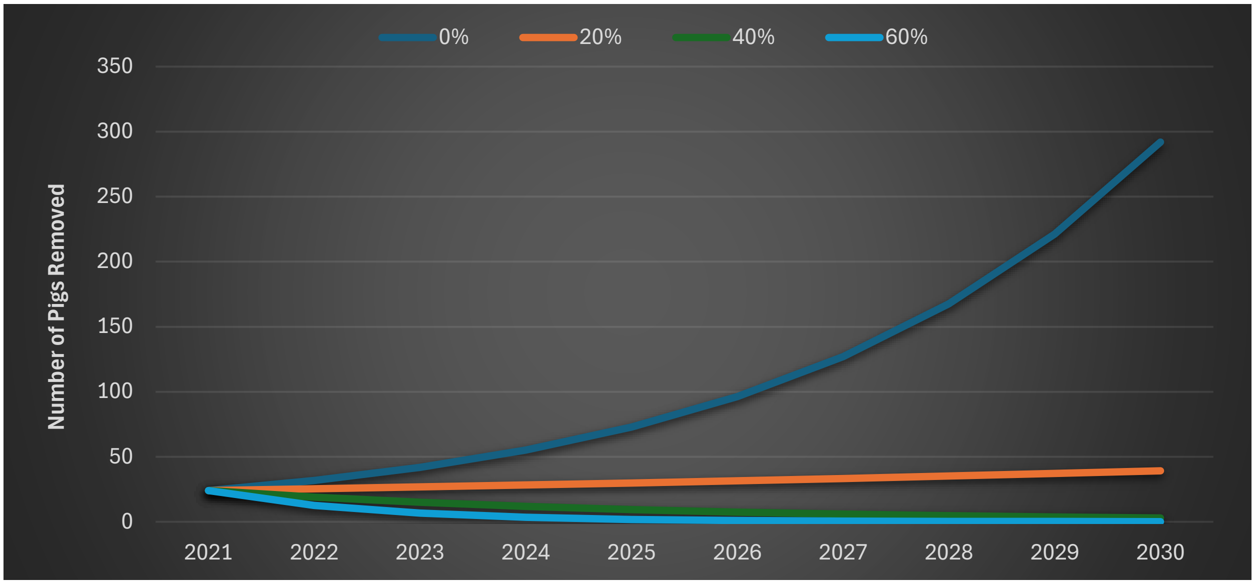

Figure 24. Yearly population growth modeling for Garin with different levels of pig removal.

California State Parks Population Analysis—Using the number of pigs removed during 2021 and an example population growth rate of 32%, the following population projections were derived for consideration (Table 14, Fig. 25). Example projections were provided for Mt. Diablo State Park only, as only two pigs were removed/recorded from Carnegie during the time period represented.

Table 10. Yearly population growth modeling for Mount Diablo State Park with different levels of pig removal.

Year	0%	20%	40%	60%
2021	306	306	306	306
2022	404	323	242	162
2023	533	341	192	85
2024	704	360	152	45
2025	929	381	120	24
2026	1226	402	95	13
2027	1619	424	76	7
2028	2137	448	60	4
2029	2820	473	47	2
2030	3723	500	38	1

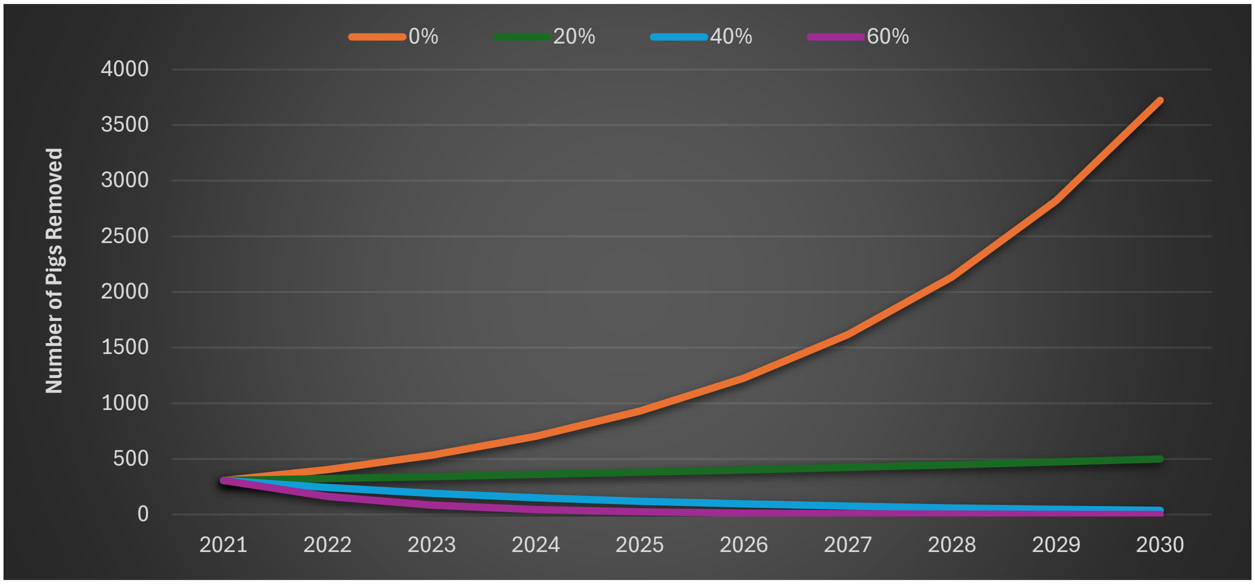

Figure 25. Yearly population growth modeling for Mount Diablo State Park with different levels of pig removal.

East Bay Municipal Utility District— Using the number of pigs removed during 2021 and a population growth rate of 32%, the following population projections were derived for consideration (Table 15, Fig. 26).

Table 11. Yearly population growth modeling for East Bay Municipal Utility District properties with different levels of pig removal.

Year	0%	20%	40%	60%
2021	434	434	434	434
2022	573	458	344	229
2023	756	484	272	121
2024	998	511	216	64
2025	1318	540	171	34
2026	1739	570	135	18
2027	2296	602	107	9
2028	3030	636	85	5
2029	4000	671	67	3
2030	5280	709	53	1

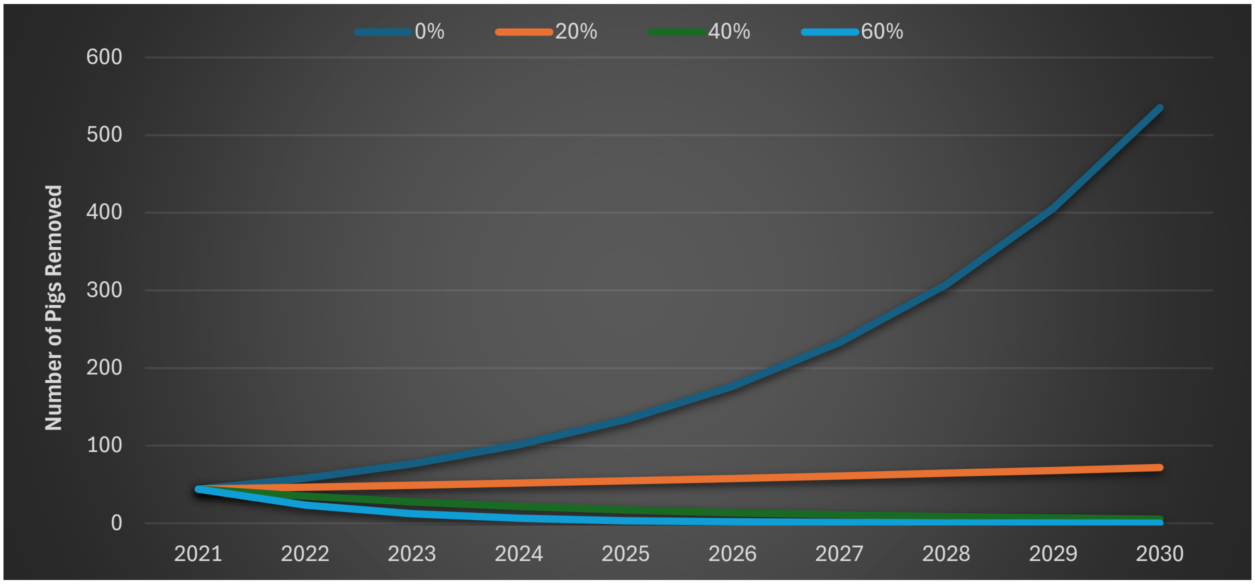

Figure 26. Yearly population growth modeling for East Bay Municipal Utility District properties with different levels of pig removal.

San Francisco Public Utilities Commission—Using the number of pigs removed during 2021 and a population growth rate of 32%, the following population projections were derived for consideration (Table 16, Fig. 27). Example projections were provided for Calaveras Reservoir only.

Table 12. Yearly population growth modeling for Calaveras Reservoir with different levels of pig removal.

Year	0%	20%	40%	60%
2021	58	58	58	58
2022	77	61	46	31
2023	101	65	36	16
2024	133	68	29	9
2025	176	72	23	5
2026	232	76	18	2
2027	307	80	14	1
2028	405	85	11	1
2029	535	90	9	0
2030	706	95	7	0

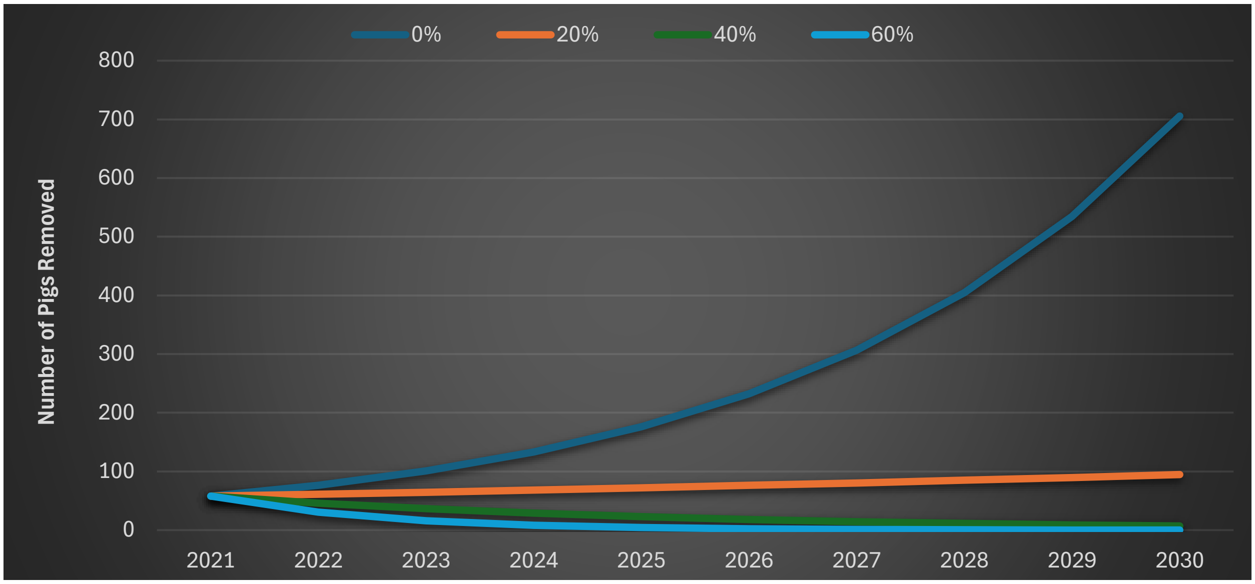

Figure 27. Population growth modeling for Calaveras Reservoir, per year, with different levels of pig removal.

<u>Pig Presence Mapping</u>

The locations for pigs that were removed from Network properties, locations for pigs removed through recreational hunting outside of Network properties, and locations of all pigs within WIR and iNaturalist data were combined as “Pig Presence” data and mapped together to evaluate the geographic distribution of pigs within and near Network properties. The boundaries for each Network property were added to those maps and provided in Fig. 28–33.

Mapping of pig data highlighted three distinct clusters of pig removal activity within Network properties: one within each of the East Bay Hills Middle LU, one within Mt. Diablo LU, and one within Mt. Hamilton LU (Fig. 28). The areas where the highest density of pig removal occurred are likely producing pigs that are dispersing towards the less dense areas.

Pigs are unlikely to travel through dense urban areas without green space or connectivity corridors and are less likely to cross large freeways, although neither are impossible. The three most prominent clusters of pig removals likely indicate interconnected populations of pigs, although, in some cases, the cluster of removals was created using pigs removed from properties managed by different partner organizations within the Network. The clustered areas within the East Bay Hills Middle LU and Mt. Hamilton LU are separated by the 580 freeway and the communities of Castro Valley, Farview, and Hayward Highland. The East Bay Hills Middle LU and Mt. Diablo LU clusters are separated by the 680 freeway and the communities of Danville, Alamo, Alamo Oaks, San Ramon, and others.

Few or no pigs were removed, or otherwise detected, within the East Bay Hills North LU using the available data sources, as was the case for Anthony Chabot, Lake Chabot, and Redwood, within the East Bay Hills Middle LU (Fig. 29–30). Containing the spread of pigs from the areas where pig removal numbers are large, would benefit regional management of the spread of pigs and best support resource protection. Recreational pig hunting data and WIR data (depredation permit data) indicated a cluster of pig removals from private properties that exist generally between Castro Valley and Brookshire, within Cull and Crow Creek Canyons. Those properties are also located within East Bay Hills Middle LU.

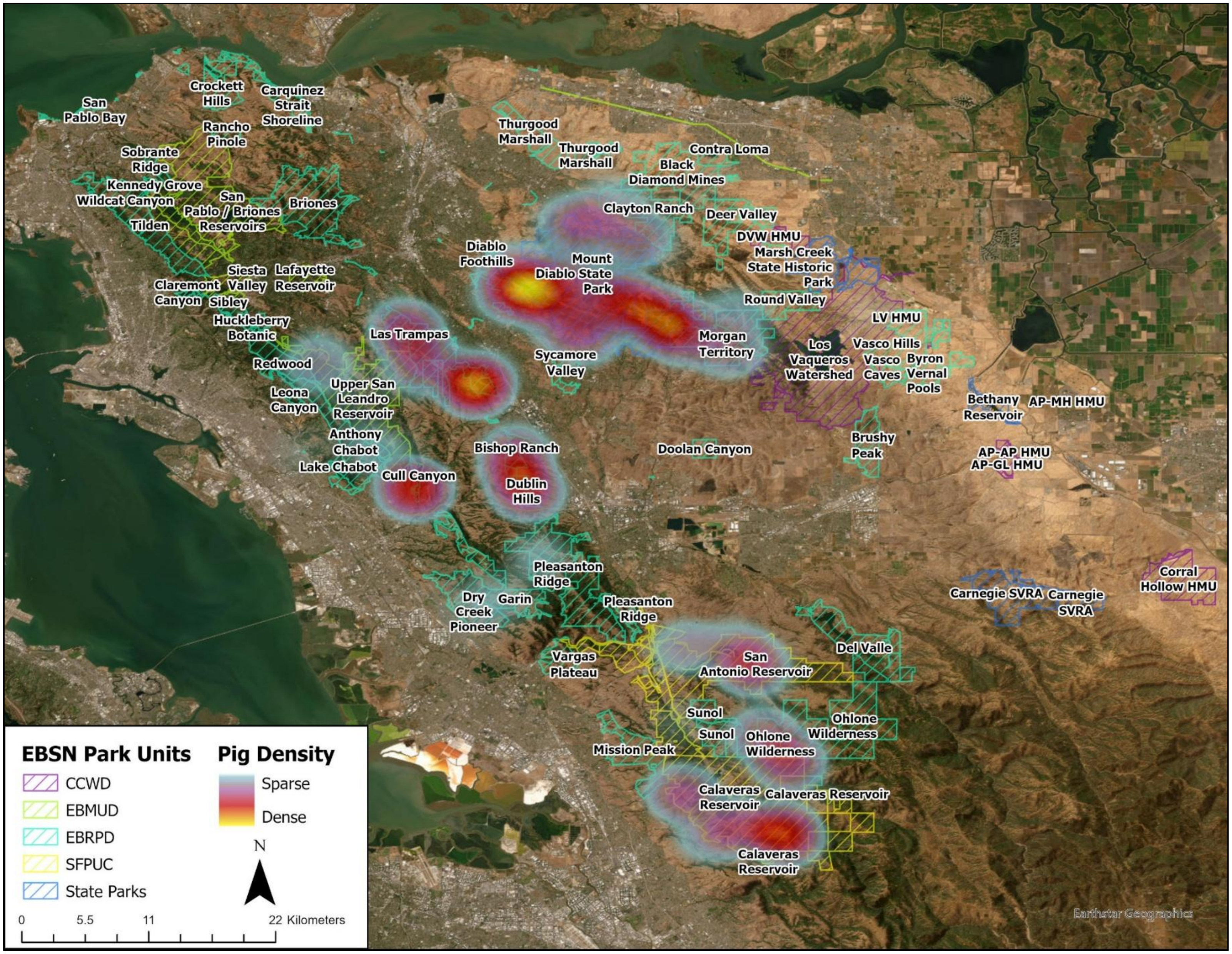

Figure 28. Heat map of pig presence using pig removal data from Network entities only, for all Sub-Regions and Landscape Units.

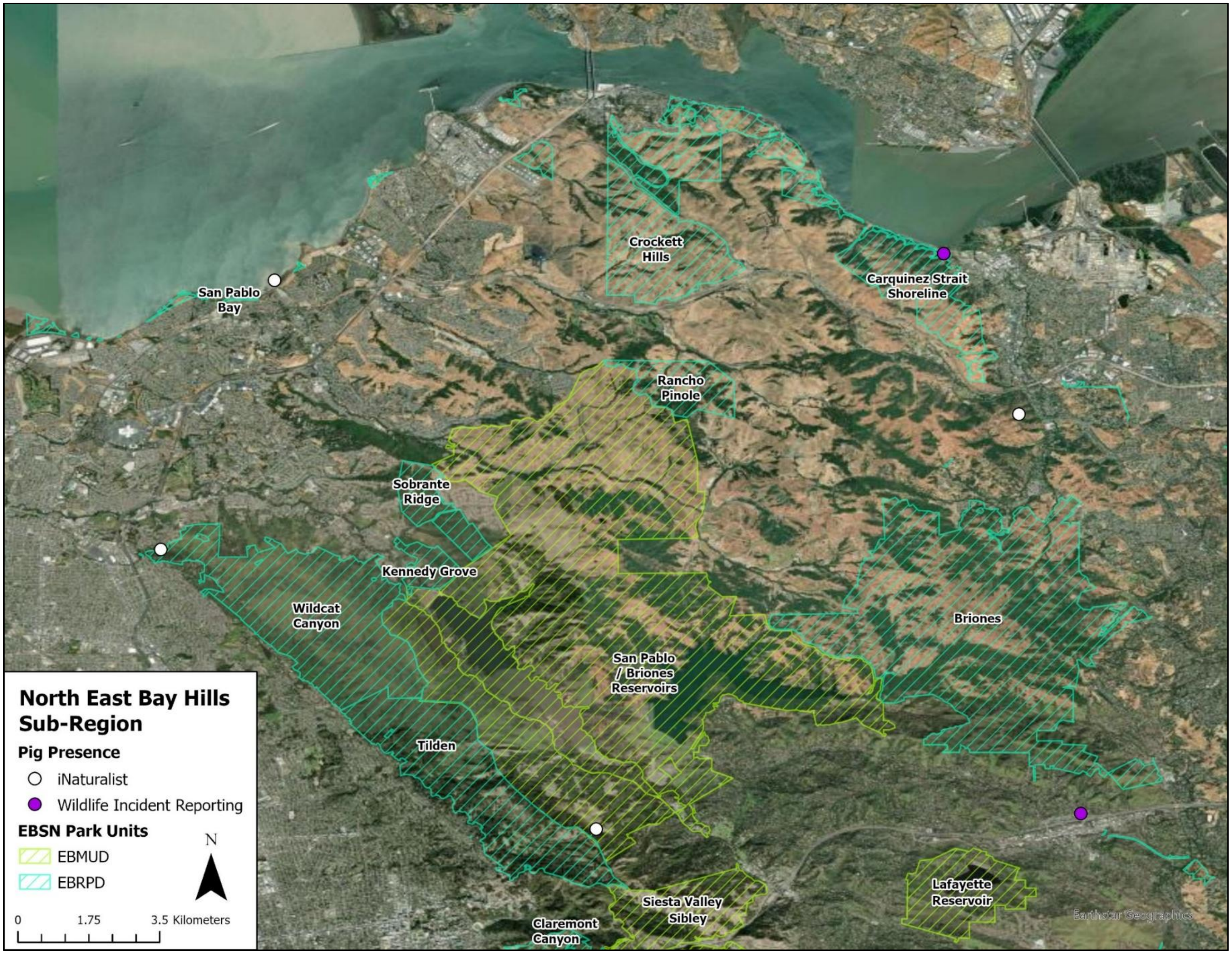

Figure 29. Pig presence map for East Bay Hills Sub-Region, North East Bay Hills Landscape Unit.

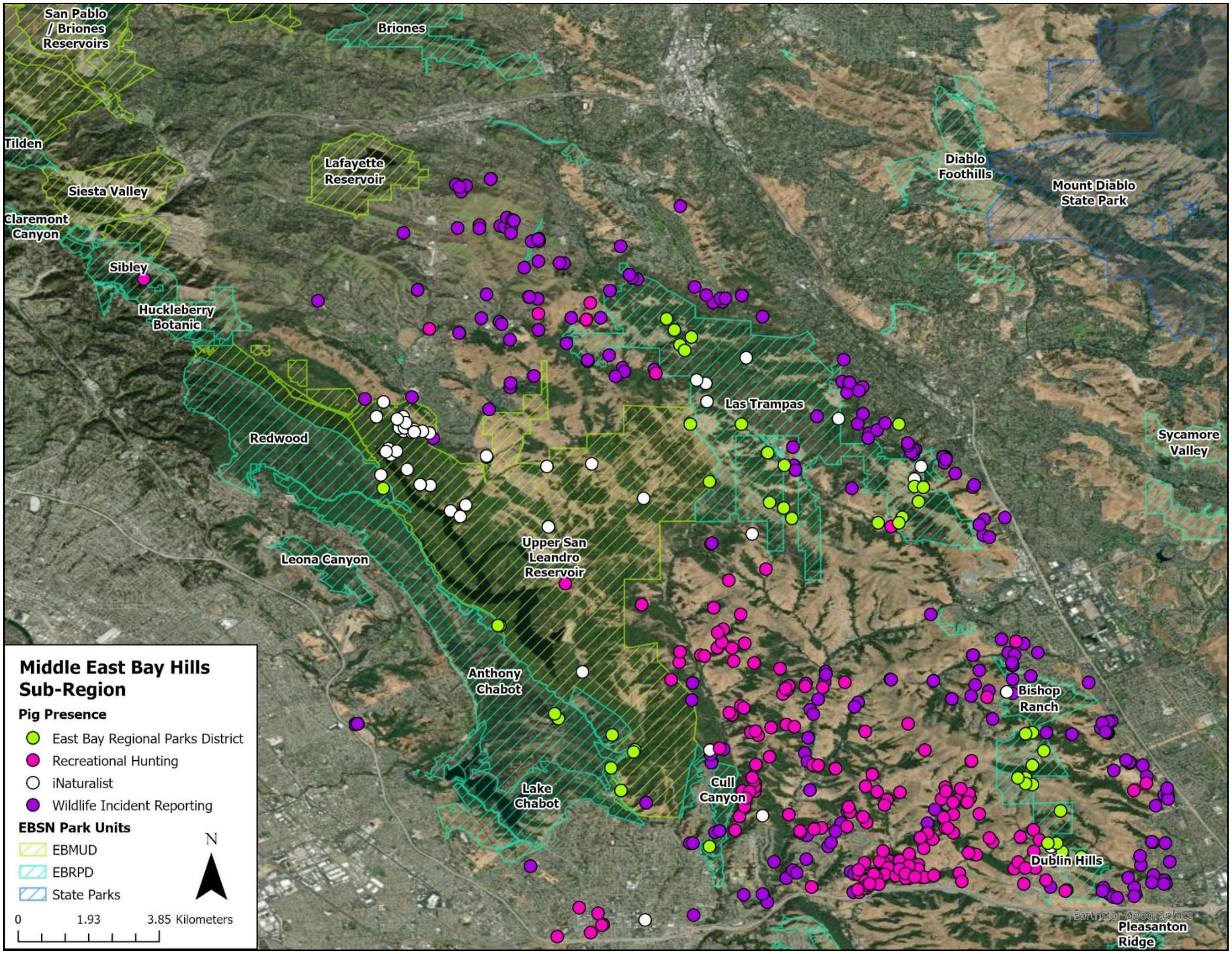

Figure 30. Pig presence map for East Bay Hills Sub-Region, Middle East Bay Hills Landscape Unit.

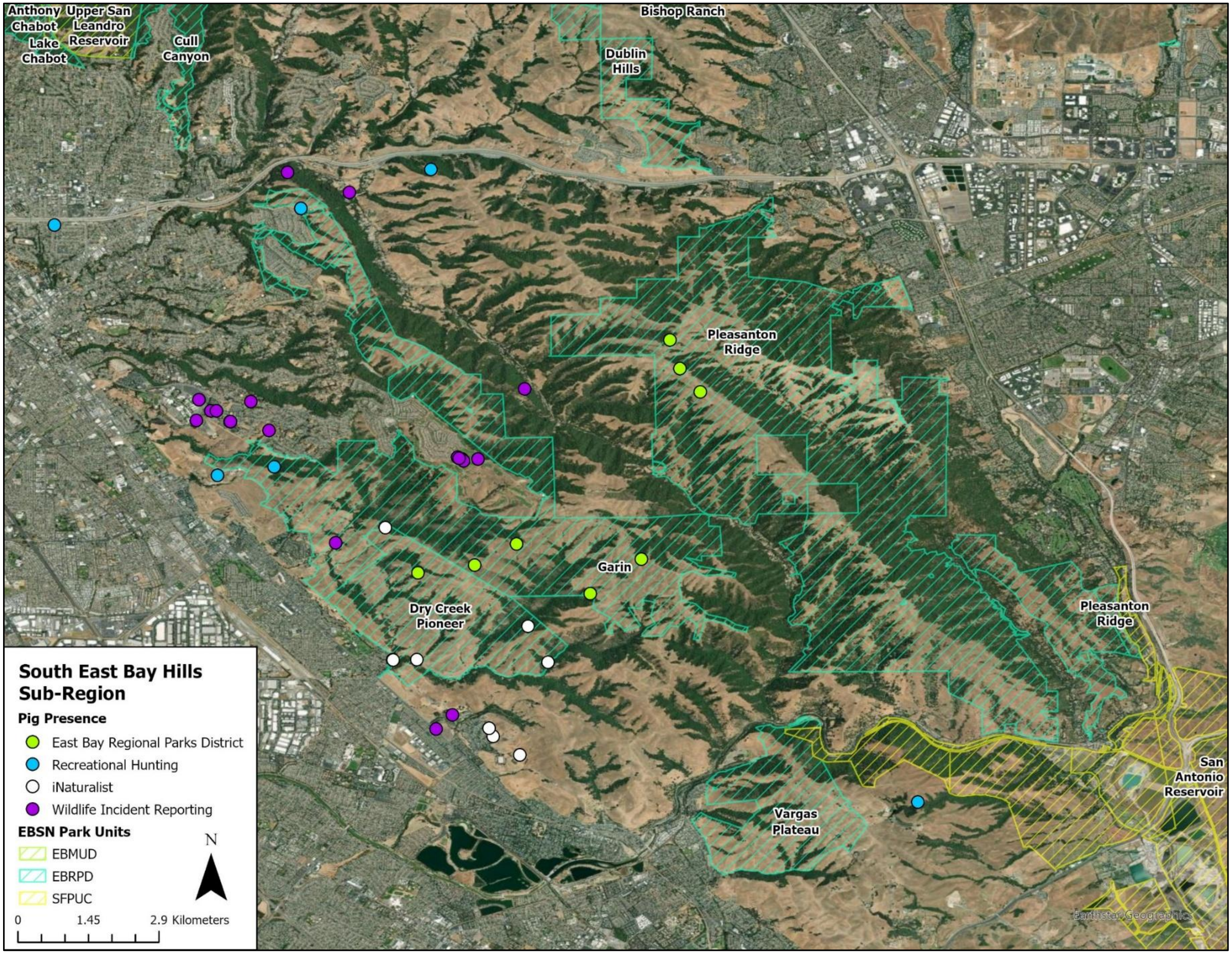

Figure 31. Pig presence map for East Bay Hills Sub-Region, South East Bay Hills Landscape Unit.

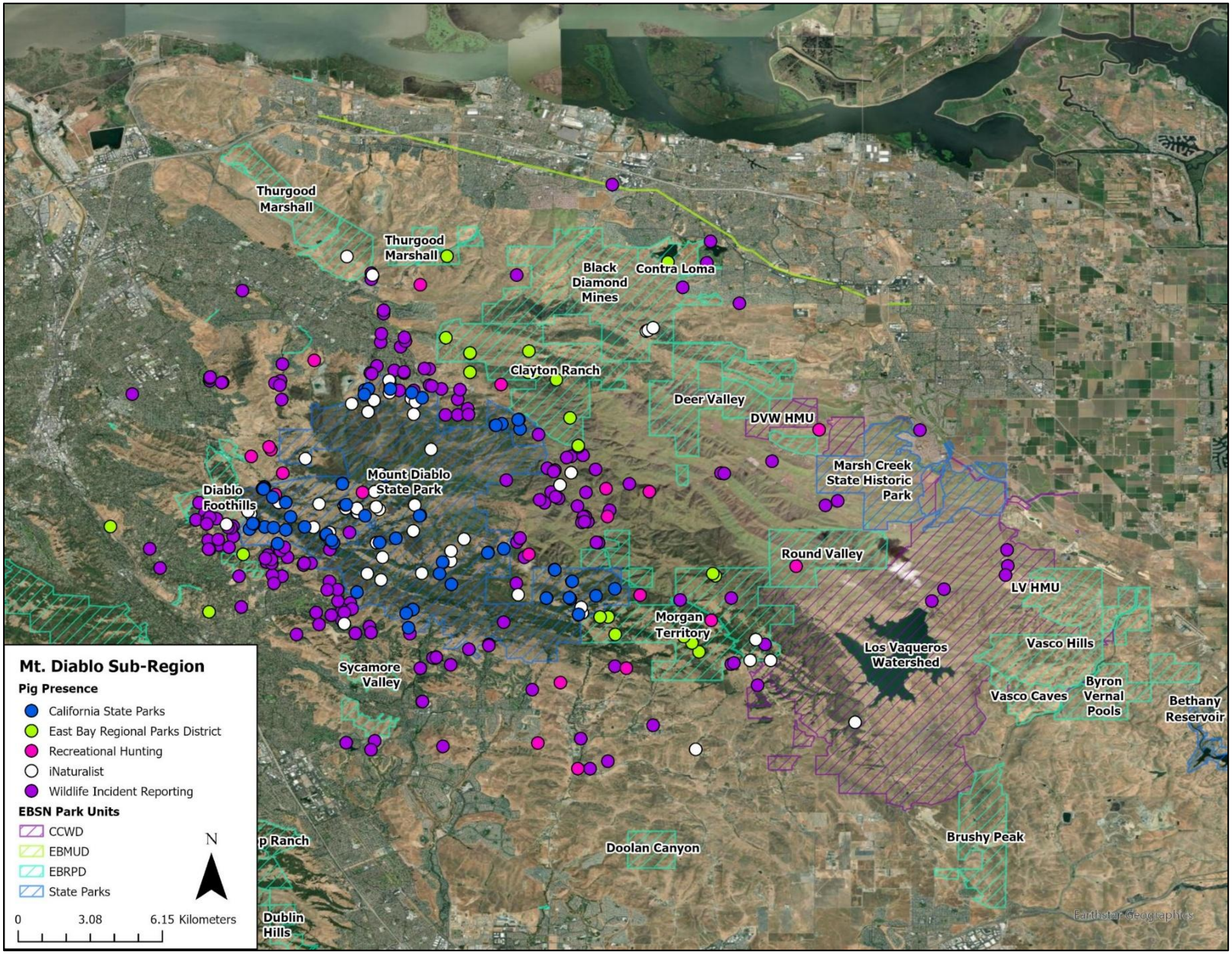

Figure 32. Pig presence map for Mt. Diablo Range Sub-Region and Landscape Unit.

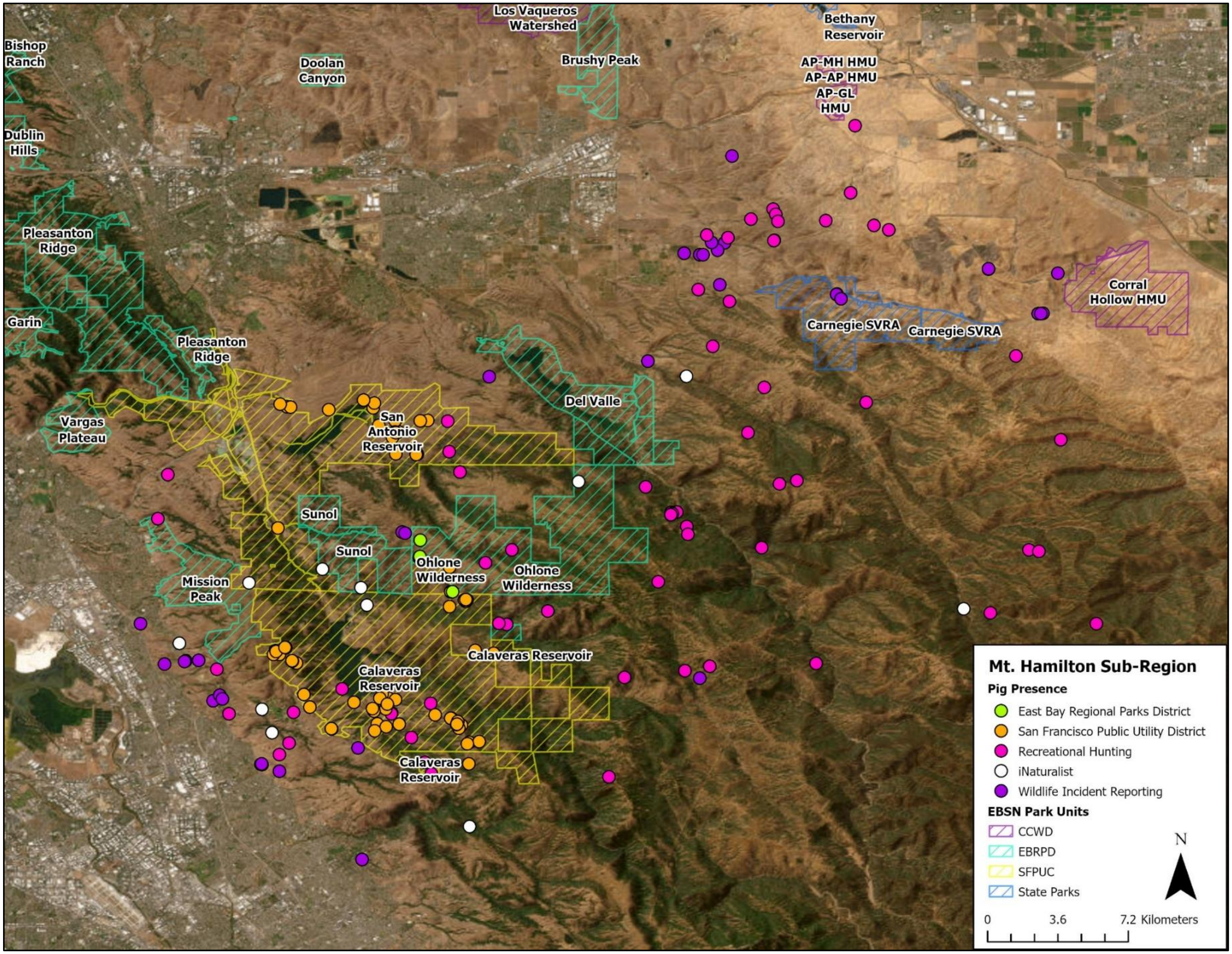

Figure 33. Pig presence map for Mt. Hamilton Sub-Region and Landscape Unit.

Sensitive Resource Data Summary and Mapping

Data regarding locations and types of sensitive resources were requested from partner organizations, including habitats, state and federally listed plant species, water sources, such as riparian areas, wetlands, or ponds, that are essential for supporting presence and existence of sensitive wildlife species, and water sources relied on by humans and livestock. Since not all sensitive resource data was able to be provided by Network organizations, known riparian areas, ponds, and wetlands known to be full of sensitive plants and animals and that could be damaged and contaminated by pigs, were obtained and mapped for consideration when allocating pig management efforts. We recommend that sensitive resources are mapped by each Network partner to help identify priority areas and to inform development of customized protection strategies for each priority area.

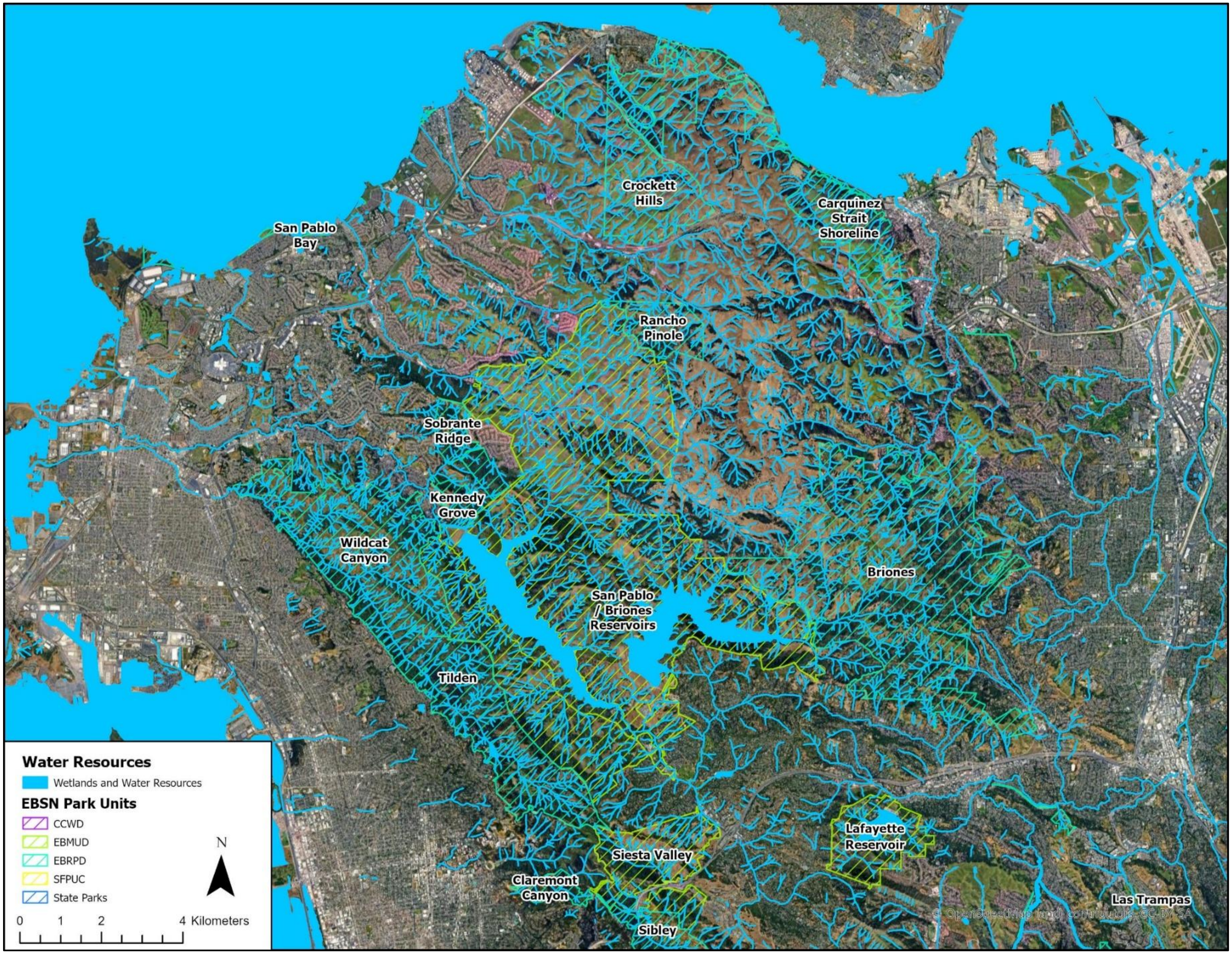

Figure 34. Wetland and water resources within the North East Bay Hills Landscape Unit.

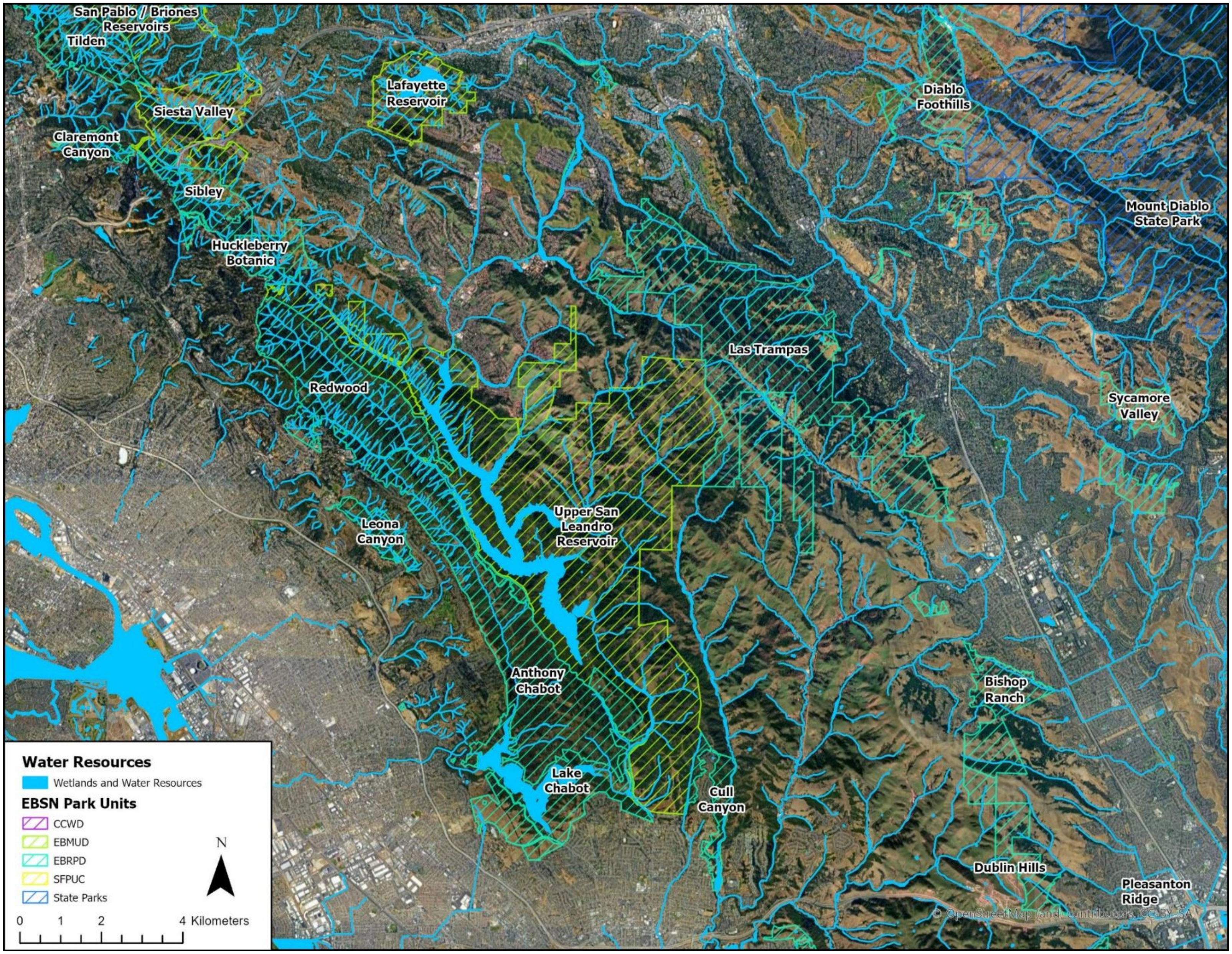

Figure 35. Wetland and water resources within the Middle East Bay Hills Landscape Unit.

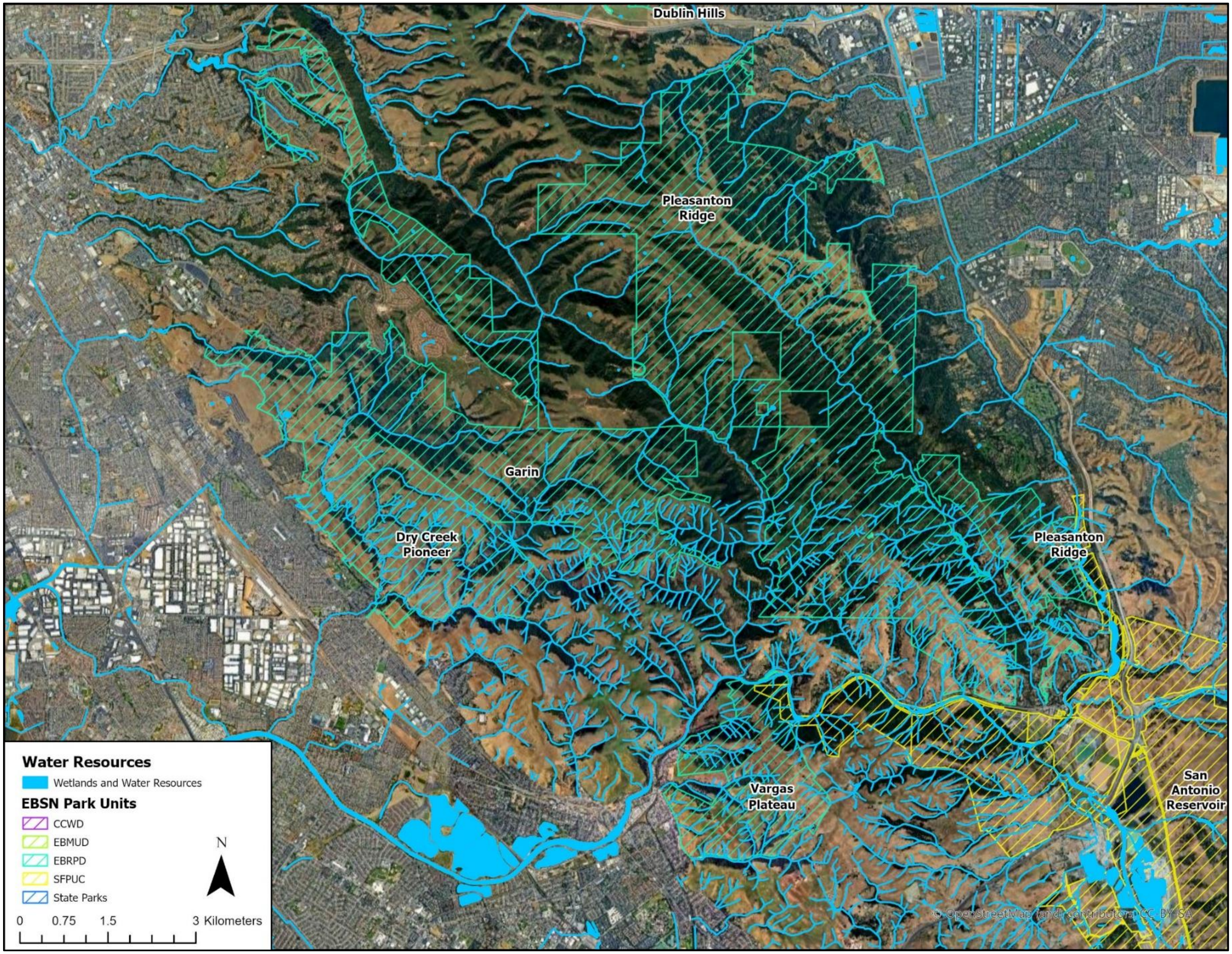

Figure 36. Wetland and water resources within the South East Bay Hills Landscape Unit.

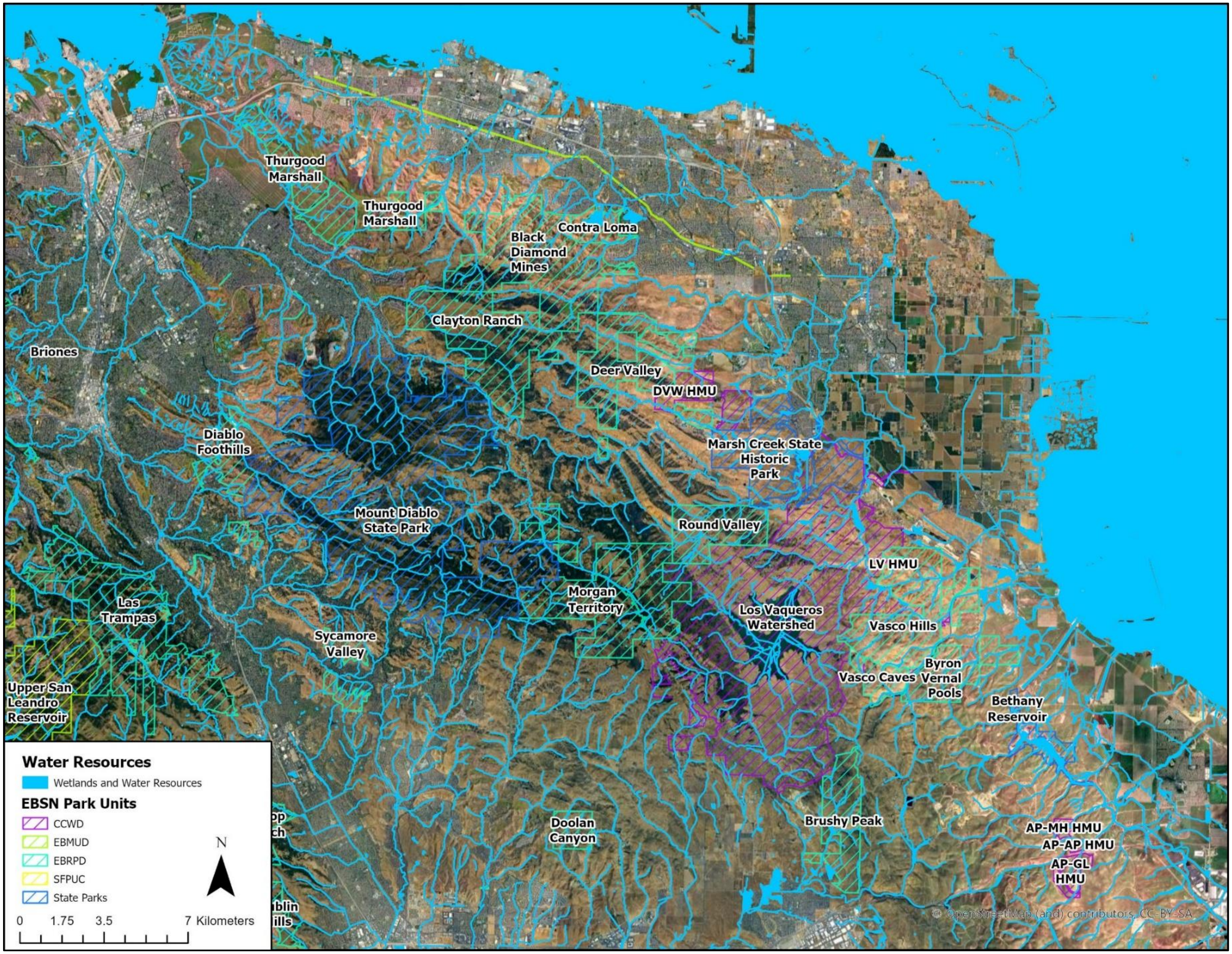

Figure 37. Wetland and water resources within the Mt. Diablo Landscape Unit.

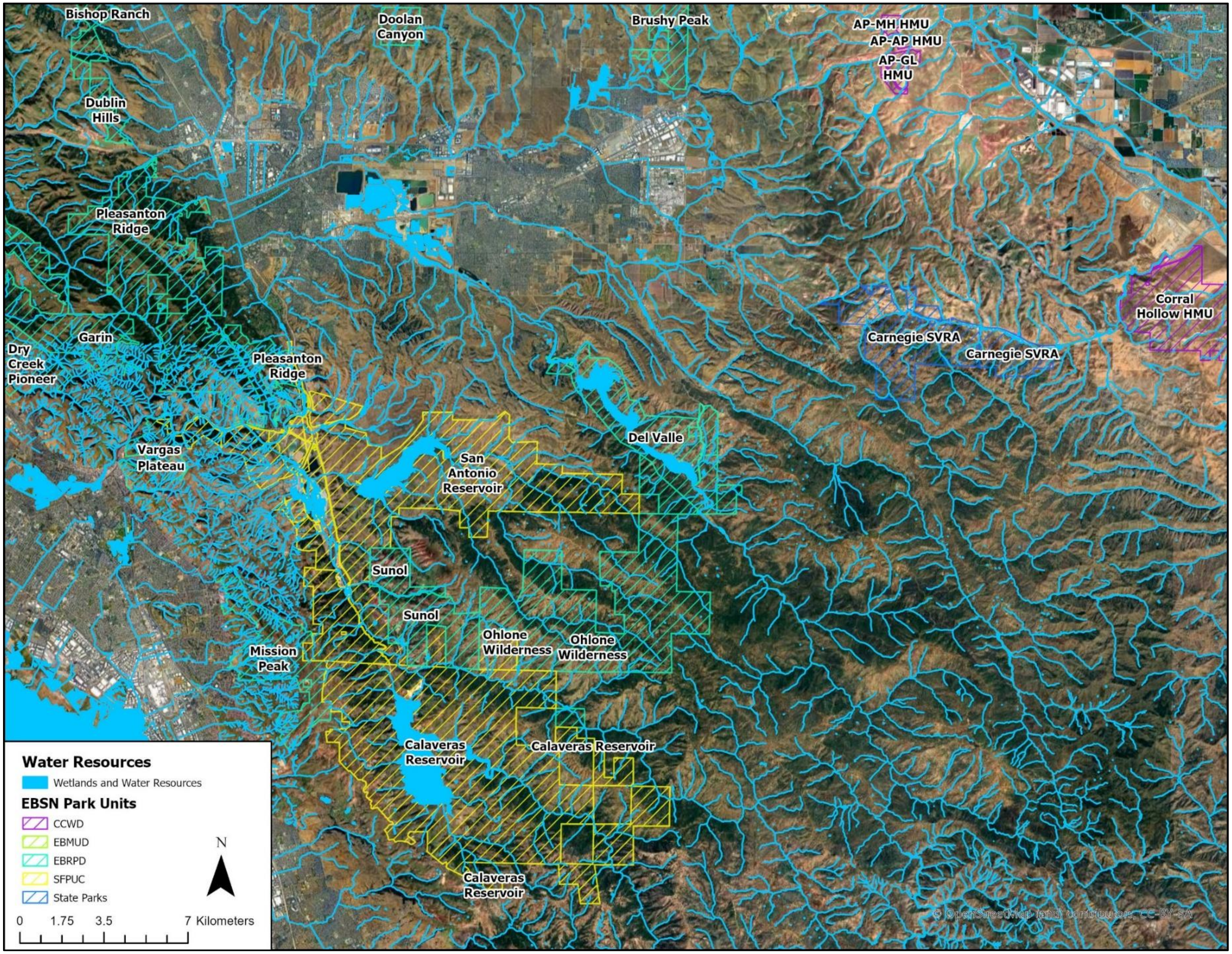

Figure 38. Wetland and water resources within the Mt. Hamilton Landscape Unit.

Habitat Suitability Mapping

Habitat suitability modeling is a method of projecting suitable habitat for an organism (Kearney 2006). Habitat Suitability Models (HSMs) relate environmental variables, frequently referred to as predictors or covariates, to the likelihood of a species occurring within a location. They can be perceived as an application of the concept of an ecological niche, as they identify and relate key environmental variables preferred, necessary, or limiting to the species (e.g., temperature, precipitation, elevation, canopy cover) to known distribution of a species (Hirzel and Lay 2008; Thuiller and Münkemüller 2010). Through relating the known distribution of a species with environmental covariates, HSMs produce geospatial predictions of likelihood of species presence across other landscapes. Habitat Suitability Models exist in multiple forms, primarily varying by the nature of species distribution data available (e.g., presence and absence data carefully collected with particular focus on confirmation of species' absence vs. purely presence data through records of species observations, sign, or hunting reports; Elith *et al*. 2011). Typical HSM utilization focuses on initially selecting variables hypothesized to be most influential to species presence, testing of interactions between these variables, determining the method of modeling based on type of distribution data available, and testing the accuracy of the model fit through fitness response curves (Hirzel and Lay 2008; Patterson *et al*. 2022).

The outputs of these models can be useful for understanding complex species niche/habitat requirements and for predicting the species' presence or absence across the landscape at both fine and coarse levels (Hirzel *et al*. 2006). This information can be critical to biologists for predicting risk of invasive species, developing efficient action plans, or identifying high value land parcels for threatened and endangered species (Scott *et al*. 2002; Guissan and Thuiller 2005). In addition, HSMs can relate and rank the relative influence of each environmental variable on the likelihood of presence. This allows managers to better understand the most important factors positively and negatively impacting species presence.

Commonly used HSM methodologies include regression models such as Generalized Linear Models (GLMs) and Generalized Additive Models (GAMs), that require both presence and absence data, and a modeling method developed specifically for modeling presence-only species data, called MaxEnt (Phillips *et al*. 2006). During testing of 21 modeling methods, MaxEnt and two derivatives of MaxEnt were classified as high-performance models with a high level of predicative discrimination, meaning high performance rates in accurately predicting presence, and all three outperformed the regression-based models (Valavi *et al*. 2022).

MaxEnt is a publicly available standalone HSM program that can also be utilized in both the R programming language and ESRI's ArcGIS software. MaxEnt is particularly valuable for its ability to form accurate predictions while minimizing necessity for data collected by trained biologists (Phillips *et al*. 2006). As presence-only data are utilized in this modeling method, publicly available information, including hunting bag reports, trapping reports, and citizen science records frequently available over many-year periods, can be easily sourced and utilized. As with other HSM methodologies, MaxEnt requires acquisition of environmental covariates and species distribution data that are geospatially distinct to the finest possible scale (Phillips *et al.* 2006).

Patterson *et al*. (2022) conducted HSM for California to identify areas where wild pigs were most likely to encounter domestic pig farming operations, thereby increasing potential for disease transmission from wild pigs to domestic pigs within those areas. Patterson acquired pig presence data, from CDFW, for locations where pigs were removed via recreational hunting throughout California and examined over 30 environmental predictors. During their model testing, Patterson identified five variables as significant in predicting suitable pig habitat in California. The five significant variables were the annual maximum green vegetation fraction, the minimum temperature of the coldest month, precipitation of the wettest month, the coefficient of variation for seasonal precipitation, and elevation.

A HSM based on Patterson's study for the East Bay Area would allow managers to select and target the highest priority habitats for pig management, efficiently allocating management efforts and increasing overall effectiveness of management. Patterson *et al*. (2022) focused on the entire state of California for the purpose of their HSM, utilizing a coarse grain for environmental variables. In the East Bay Area, finer grain habitat data were available and allowed for more specific delineations but necessitated creating a new HSM at that resolution and confined to the greater East Bay Area. To efficiently produce a new HSM, within the timeframe and scope available for this Plan, the five most significant environmental variables reported in Patterson *et al*. 2022, were used instead of re-testing each variable. National Aeronautics and Space Administration's (NASA) Moderate Resolution Imaging Spectroradiometer (MODIS) remote sensing data were used to determine temperature and green vegetation, and NASA's North American Land Data Assimilation System (NLDAS) remote sensing data were used to determine precipitation. Elevation data were obtained from the U.S. Geological Survey (USGS). Pig presence data, needed to inform the model of likely highly suitable habitat, consisted of a combination of Network, WIR and hunter removal locations acquired from CDFW, and observations sourced from iNaturalist. All environmental and presence data were limited to 2018 through 2022. Environmental variables were individually averaged across the 5-year period. Wildlife Innovations input environmental and pig presence data into ESRI's ArcGIS, producing a MaxEnt HSM. Results were projected using ESRI's ArcGIS, mapped, and ranked by suitability (Fig. 39–44).

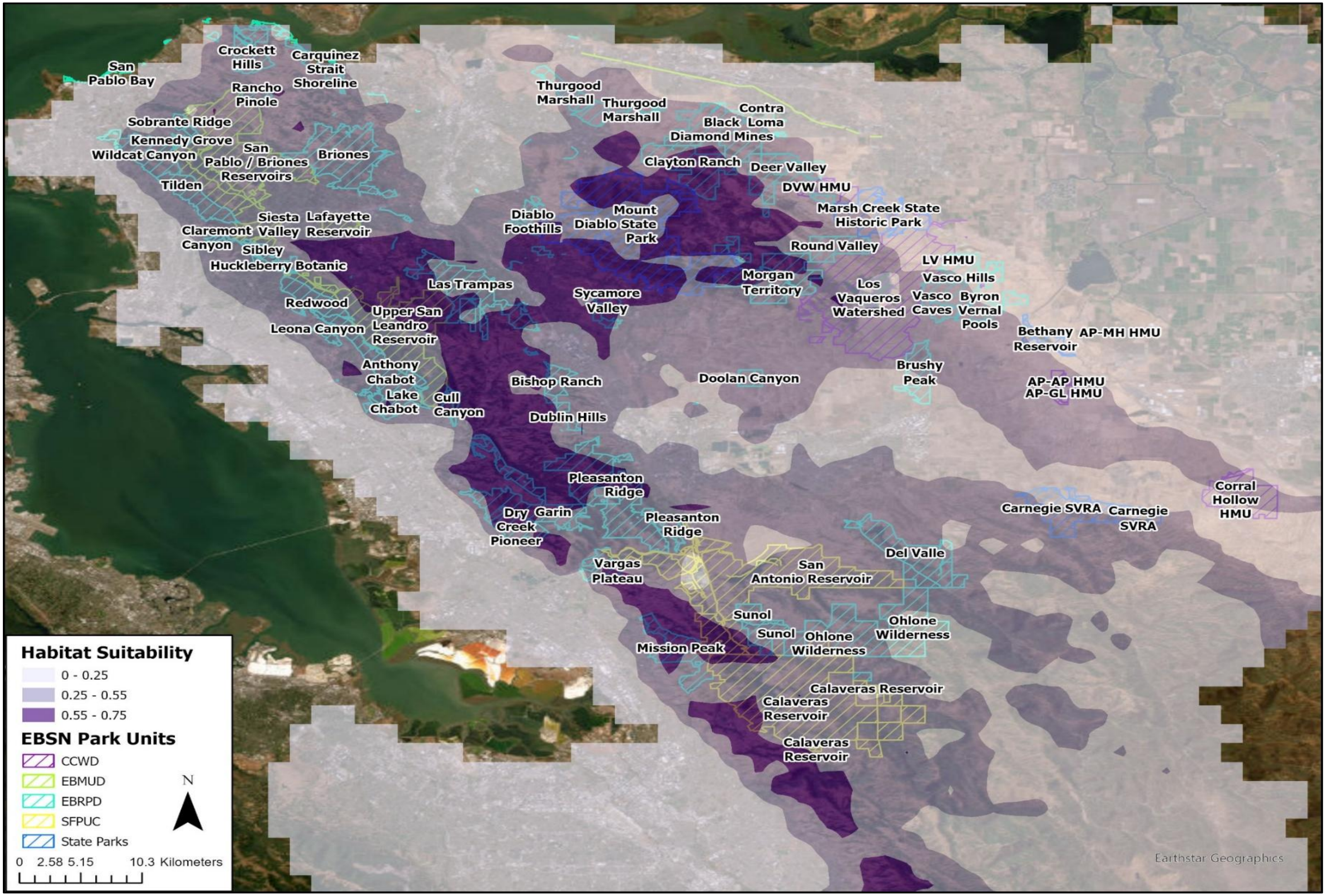

Figure 39. Habitat suitability map for all Sub-Regions and Landscape Units.

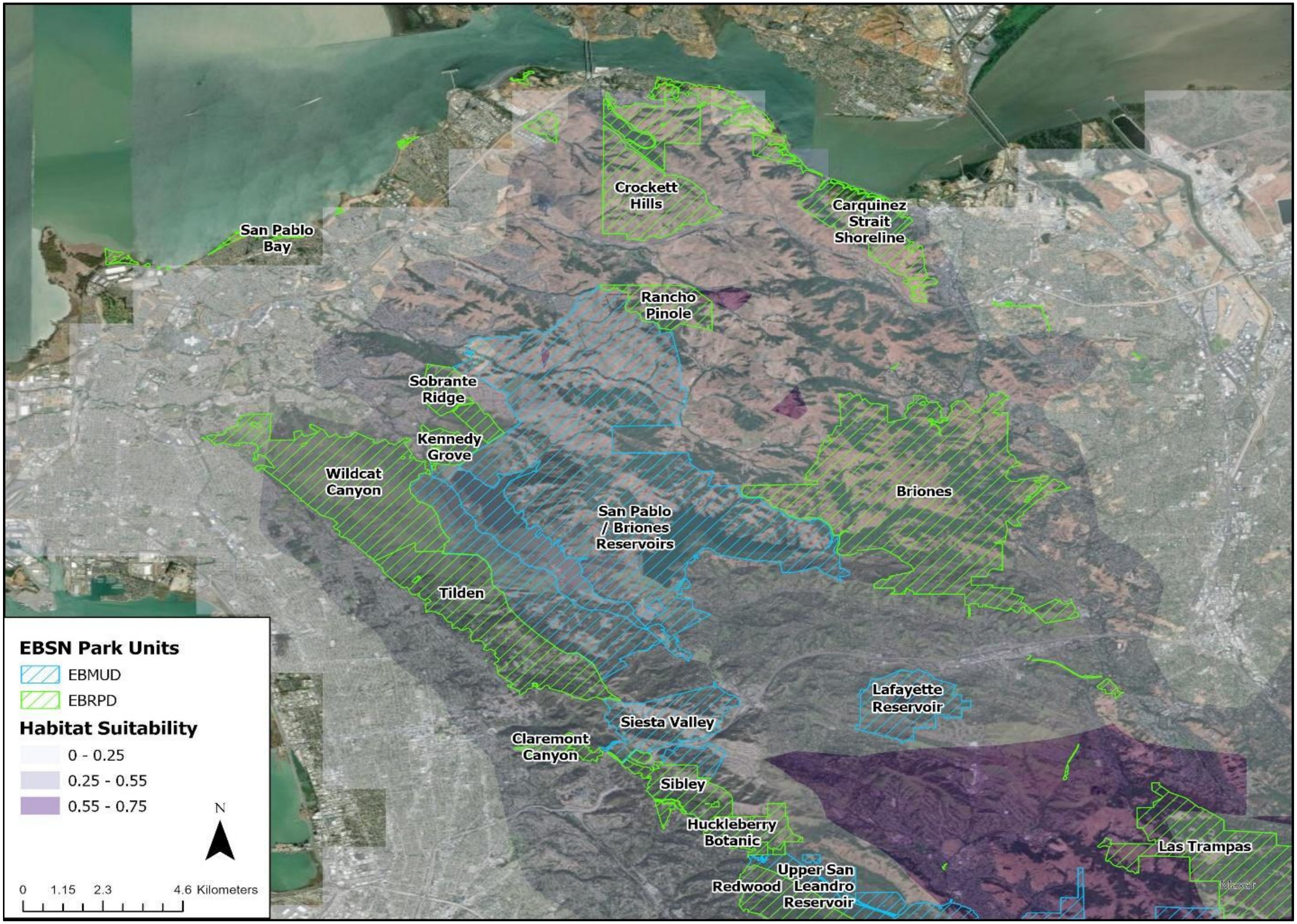

Figure 40. Habitat suitability map for East Bay Hills Sub-Region, North East Bay Hills Landscape Unit.

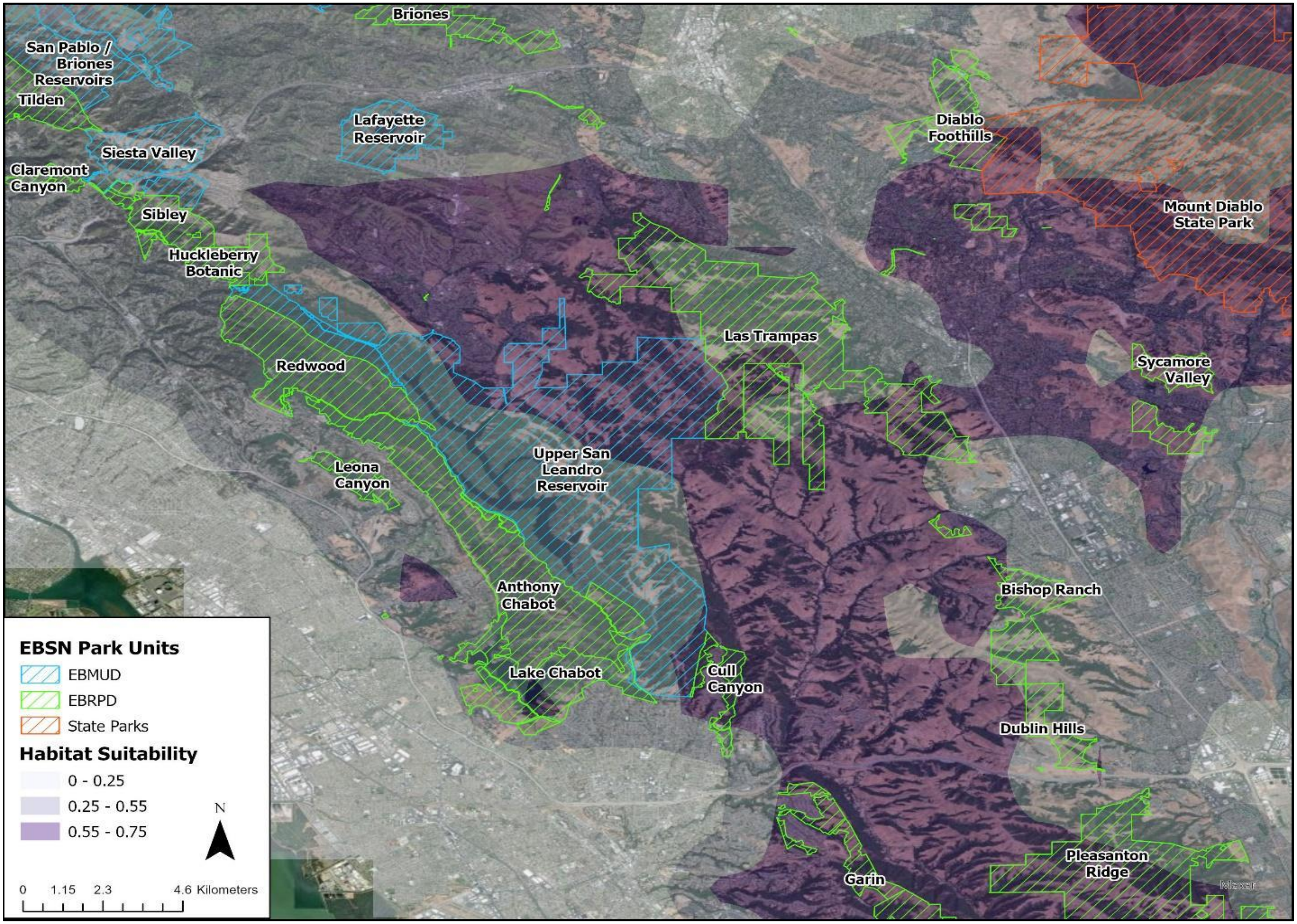

Figure 41. Habitat suitability map for East Bay Hills Sub-Region, Middle East Bay Hills Landscape Unit.

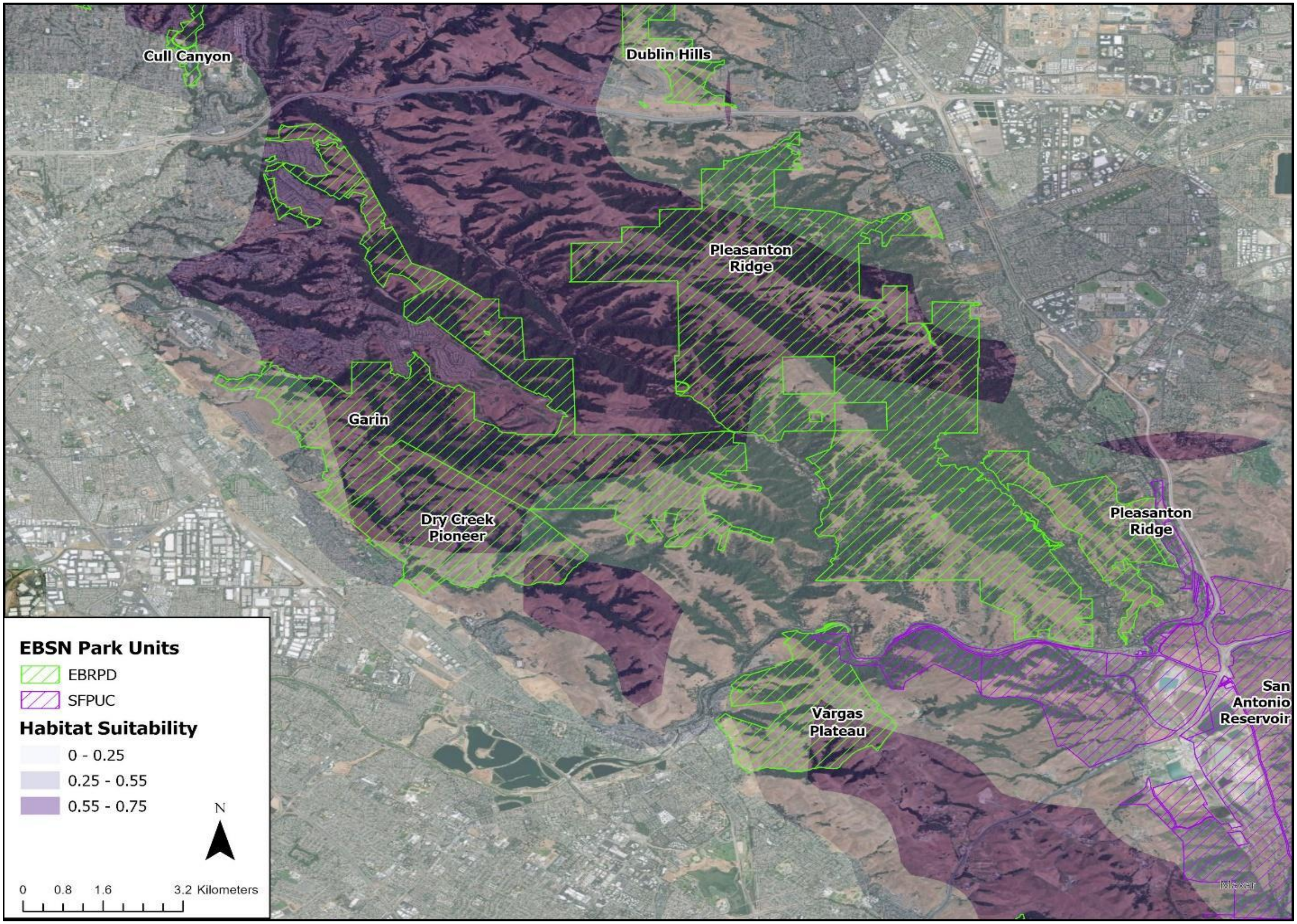

Figure 42. Habitat suitability map for East Bay Hills Sub-Region, South East Bay Hills Landscape Unit.

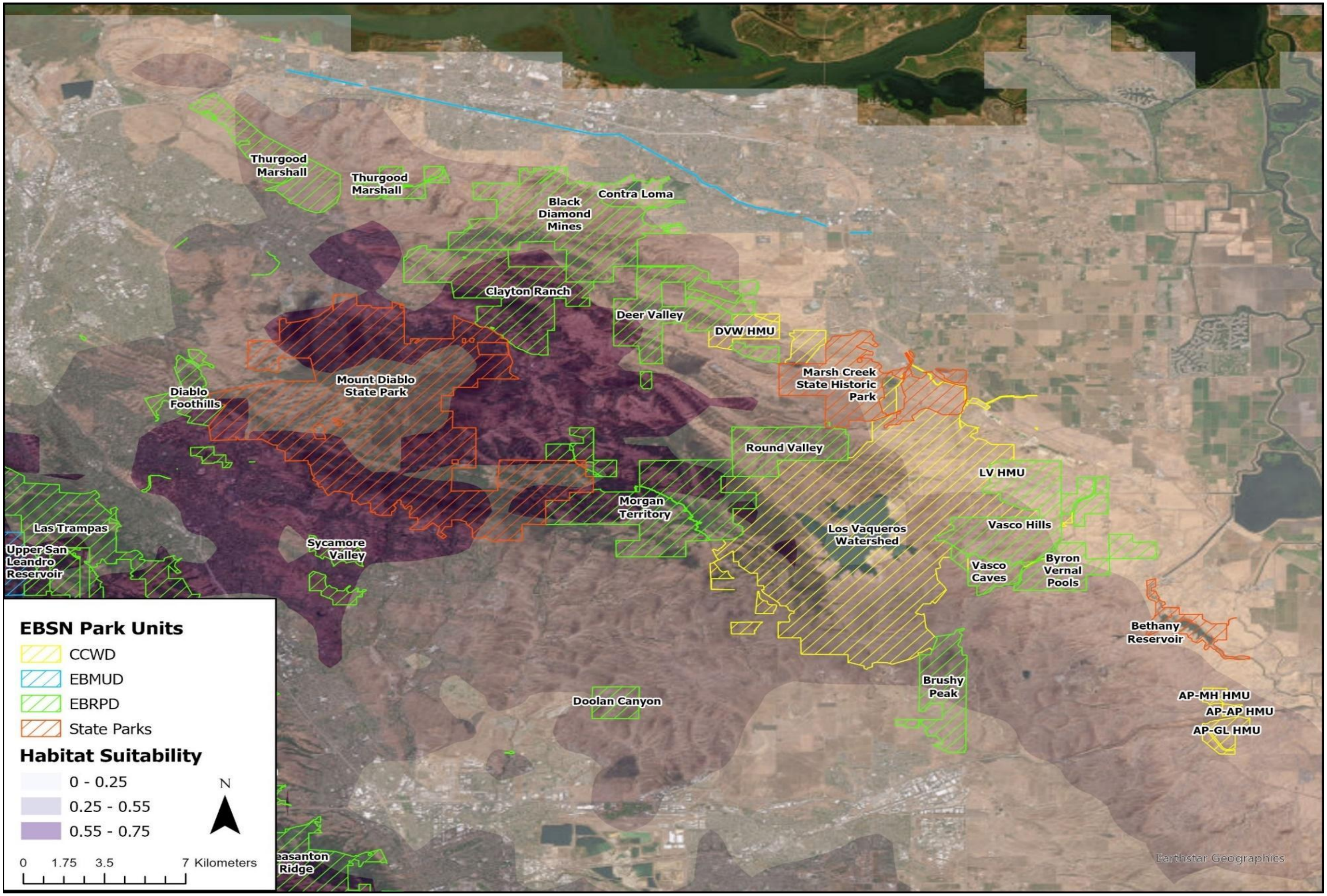

Figure 43. Habitat suitability map for Mt. Diablo Range Sub-Region and Landscape Unit.

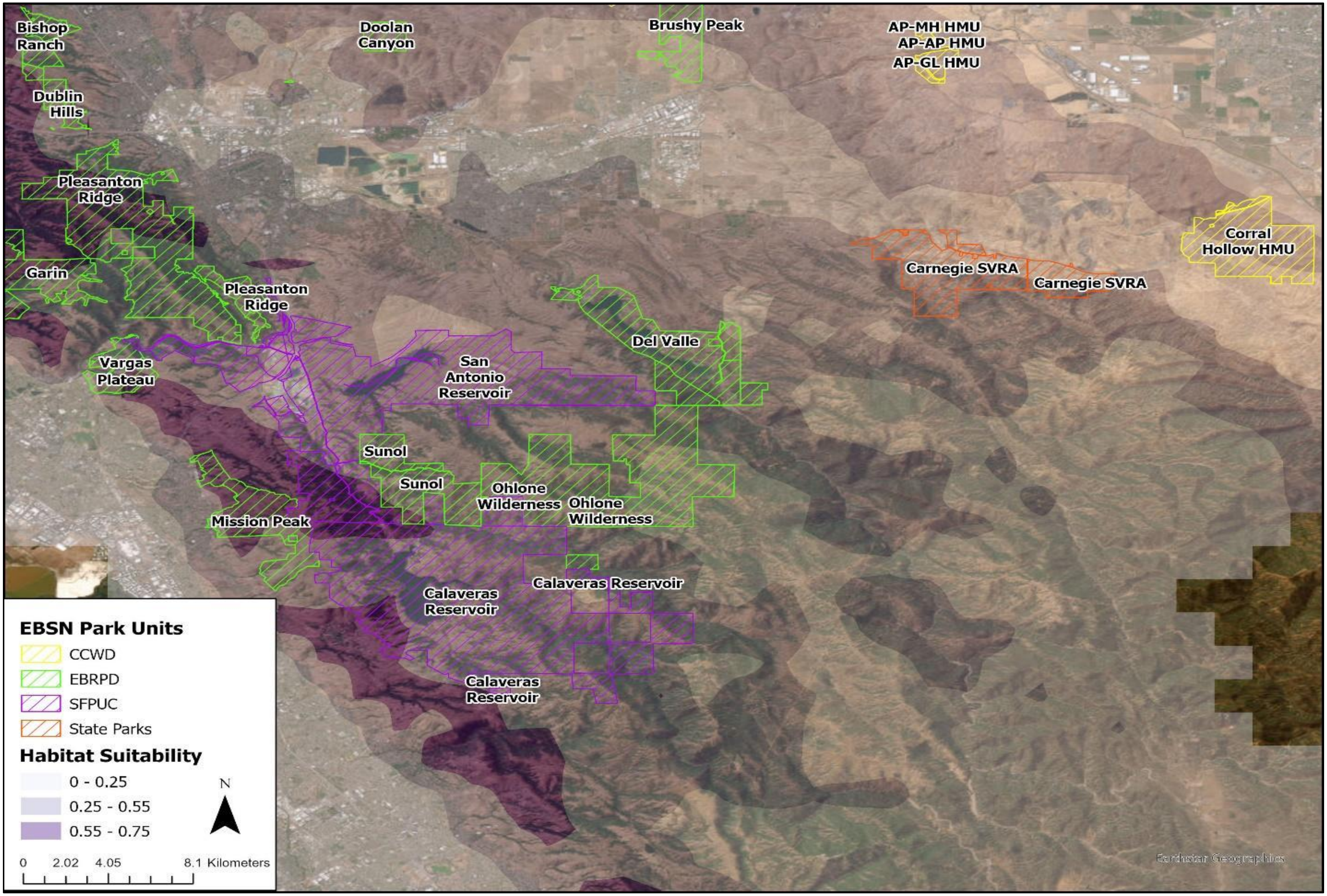

Figure 44. Habitat suitability map for Mt. Hamilton Sub-Region and Landscape Unit.

SECTION 8: PIG POPULATION MONITORING STRATEGIES

Successful protection of the resources managed within Network properties for pigs will rely on a robust and efficient program to monitor pig abundance and track damage to help inform management strategies. Critical aspects of developing and maintaining a successful pig management program are to understand pig movements within and between properties and to identify population density and demographic rates to better inform adaptive management efforts (VerCauteren *et al*. 2020).

Some systems are already in place within individual Network entities, but the systems are not congruent or digitized, and collection protocols are not followed to allow data to be compared between or across organizations. Data collection strategies should be developed and standardized across all Network partners to facilitate improved and coordinated regional management of pigs. Effective monitoring of pig population size and activity are essential to support informed management. By documenting and tracking damage caused by pigs within an effective monitoring program, land managers can strategically implement damage prevention measures. Once damage prevention measures and/or pig removal are implemented, monitoring is essential to track the efficacy of the efforts employed. Monitoring changes in pig population and damage over time will inform future management strategies adaptively.

Creating a robust system to monitor, report, and track pig observations, signs, and damage, as well as to manage pig deterrence, exclusion, and removal efforts, could involve the following key steps:

1. System Design and Development

- Develop a standardized framework for collecting data on pig sightings, damage, and management efforts to be used by all Network entities. This should include:
    - Record all observations of pigs, including the location, time, and number of pigs observed.
    - Record all damage detected, including the type and extent of damage caused by pigs.
    - Record physical signs of pig presence (tracks, rooting, etc.).
    - Record all efforts associated with pig deterrence, exclusion methods, and removal efforts (traps, hunting, etc.).
    - Identify and implement a user-friendly app (or multiple) for field staff and park visitors to record observations and efforts in real-time.

2. Standardization

- Develop and adopt common data fields and protocols for the collection and entry of each type of data to ensure consistency across Network organizations.
- Develop training materials and require that all personnel that may collect data are trained on how to use the system and the importance of standardized data collection.
- Create standardized reporting templates monthly or quarterly, and annual summaries of pig activity and pig population control efforts.

3. Collaboration and Adoption

1. Encourage all Network organizations to adopt and adhere to the data collection and maintenance system, emphasizing the benefits of a unified approach.
2. Establish data sharing agreements among partners to share data and insights, ensuring confidentiality where needed.
3. Hold regular meetings or calls to discuss findings, challenges, and improvements to the system.

4. Evaluation and Reporting

- Develop standard program performance metrics, or key performance indicators (KPIs) to measure the success of pig control efforts and the system's overall effectiveness.
- Conduct an annual review of the data collected and the outcomes of control efforts to refine strategies and tools.

This system should be flexible enough to adapt to local conditions while maintaining enough standardization to allow for effective data comparison and collective analysis across the Network.

In addition to creating more efficient ways to monitor pigs through in-person observations, two important monitoring tools to better understand pig population dynamics and movements are Global Positioning System (GPS) collars and camera traps.

Camera Traps

Camera traps have been used to assess and monitor a variety of wildlife species and wildlife populations. They can detect the presence of elusive wildlife, monitor their movements, and identify the timing of movements or specific behaviors that may otherwise go undetected. In some cases, such information can be obtained at a much lower cost and with the ability to monitor larger areas than employing in-person monitoring or surveillance. Since pigs are sensitive to human presence, the use of remote cameras may also increase detection.

The usage of cameras is essential for effective management, as information on local abundance is crucial for a successful pig control program (Engeman *et al*. 2013). The use of cameras in pig population management could gather crucial data on the number of pigs, their active periods, and in some cases, track individual pigs or resight tagged animals. The data collected could provide insights into the number of pigs, their age classes, the first appearance of piglets, and the number of piglets produced (Engeman *et al*. 2013). This ongoing surveillance could reveal how quickly pigs repopulate areas after removal efforts, allowing for more precise planning of targeted management actions. A study done by Teton *et al*. (2016) found that camera trap surveys proved to be more reliable when estimating population abundance of pigs than line-transect surveys. Through capture-mark-recapture (CMR) analysis using camera resighting, population densities can also be estimated (Omasta *et al*. 2021). By providing estimates of population numbers before, during, and after pig removal operations, cameras can help support more informed decision-making in pig population control strategies (Fischer *et al*. 2020).

Rapid population estimates for pigs are possible using 10-day camera surveillance (Snow *et al*. 2020). This strategy allows wildlife managers to attain reliable pig population estimates needed for effective management without prohibitively significant investments of time and money required by other methods.

Cellular transmission-capable cameras can be especially valuable for wildlife management programs which have project sites with cellular service. Cellular cameras may be used for monitoring pig presence and activity, which can allow fewer personnel to monitor larger areas by reducing travel and to monitor pig activity without disturbing bait and trap sites, thereby increasing efficiency. Such devices may be used to provide real-time notification of wildlife presence and activity and may also be used to monitor traps or evaluate behavior of wildlife when interacting with or avoiding trap sets. This reduces the amount of personnel travel time and field time necessary to support those management efforts. Cellular camera systems may be used with remote-activated cage traps to maximize potential for an entire sounder to be captured, increasing the effectiveness of a removal program.

Pig population assessment using cameras should be conducted at least annually and possibly twice per year during the early stages of population evaluation and management program development. Depending on funding and the desired outcome of camera surveillance, single cameras, clustered cameras, and camera grids could be used. Cameras can be placed within a grid (e.g., 10x10 km grid; Jennings and McCreary 2016) or grid system (500 m x 500 m, 750 m x 750 m, 636 m x 636 m; Snow *et al.* 2020, Kilgo *et al*. 2023), with one or two cameras placed within each grid cell. Placement should be based on proximity to wildlife trails, mounting locations, and camouflage options to hide the cameras (Jennings and McCreary 2016). At a minimum, camera trap stations should be deployed at areas with recent pig activity (i.e., rooting, wallowing, game trails) and have those stations baited (e.g., acorns, corn, mast), to increase the likelihood of detecting pigs via cameras. Grids consisting of between 10 and 55 cells, each containing one camera, have proved effective in determining pig density (Snow *et al.* 2020, Omasta *et al.* 2021, Kilgo *et al.* 2023). Cameras can be deployed before and after management actions to quantify effectiveness on diminishing pig populations (Snow *et al.* 2020).

Satellite (GPS) Collars
Satellite telemetry, through attachment of GPS tracking devices to individuals, is a valuable tool for monitoring wildlife species and wildlife populations. These devices are typically attached via collars and have been used to identify and track wild pig habitat use, spatial ecology, and survival rates (VerCauteren *et al*. 2020). The data obtained by these devices can help managers better understand daily and seasonal movements, exploitation of food resources, and movements within and between properties, all of which may be used to inform adaptive and targeted management efforts. Collar data combined with camera data may help to identify locations in Network properties with high densities of pigs. These areas can function as population sources to support population recovery following removal efforts. Potential population sources need to be identified, evaluated, and targeted as part of effective pig population control efforts. In addition, collaring of pigs can be used to determine sounder home range size, recolonization speed to areas where pigs had been removed, and to assess if they made long excursions to other high priority areas such as agricultural resources (Lewis *et al*. 2022, Theuerkauf *et al*. 2023). Continual monitoring of collared pigs following removal events is essential to detect remnants of partially eliminated sounders and can additionally be used in the Judas pig method to locate pigs remaining on the landscape for targeted removal (Lewis *et al*. 2022). Through GPS collar data, survival and recruitment rates can also be estimated accurately using mark–recapture methods, where transmitter data are used to replace physical recapture (Williams *et al*. 2002). Variation in mortality rates and survival temporally or by gender particularly influences population growth or decline (Bond *et al*. 2001, Gehrt 2005). Annual and seasonal survival rates of mortality by gender are beneficial pieces of information that can help wildlife managers make the most informed decisions on population control efforts (Choquenot *et al*. 1996, Gehrt 2005). Satellite collar data can help to better understand all of these metrics for a given population.

Section 9: Pig Management Methods

Relatively few effective methods are available to control wild pigs, and even fewer are legal within California. Available pig management methods fall into two general categories, nonlethal and lethal. For nonlethal control, the only method known to be effective in mitigating conflict with pigs is fencing. Fencing is tremendously expensive to install and requires regular maintenance, which is also costly. No other pig deterrence methods have been documented to be effective for extended periods of time.

Lethal management methods generally fall into the categories of trapping and shooting. Shooting is limited in urban environments and requires well trained personnel with familiarity of intended control areas as well as pig and human use of these properties to support safe and effective pig removal. Shooting from aircraft (e.g., helicopter) although legal and effective in some states, is not likely not feasible in most areas of California for legal and public-perception reasons. It is also may be ineffective in areas with thick vegetation but can be extremely effective where possible. Currently, there are no poisons registered for use for pigs in California.

Nonlethal Management for Wild Pigs

Exclusion of Wild Pigs—Within pig management programs, fencing has most often been used where the cost of removal was too extreme or the landscape too complex to allow effective removal (Hone and Atkinson 1983, Choquenot et al. 1996).

Fencing can be an effective method of wild pig exclusion, but generally only within small-scale areas (Barrett *et al*. 1988). Creating pig-proof fencing around a smaller park before eradication can be effective in excluding new pigs from immigrating into those areas. Creating "pig-proof" fencing, however, can be very expensive (Mayer and Brisbin 2009). "Pig-proof fencing" is defined as a fence that will not allow a wild pig to cross over, through, under, or around (Mayer and Brisbin 2009). This requires fencing to be tall enough (3-3.5 ft), deep enough into the ground (~1 ft) and made of a material that wild pigs cannot damage or break (Mayer and Brisbin 2009). Successful fencing for excluding pigs is made of heavy woven or mesh wire fence (maximum of 6-inch spacing) with the base buried in the ground, combined with one or more electric wires surrounding the outside barrier of fencing (Littauer 1993, Barrett and Birmingham 1994, Stevens 1996, Caley 1999, Land Protection 2001, and Mapston 2004).

Costs of fencing vary based on the materials used to complete the desired fencing design, the geographic location, and the topographic and location access challenges. Based on eight studies that have constructed "pig-proof" fencing before 2009, the estimated cost per linear kilometer of fencing was between $20,000-25,000 at that time (Mayer and Brisbin 2009). In 2003, Pinnacles National Park constructed a complete "pig-proof" fence that ran 24 miles and enclosed 14,500 acres of land. The entire fence cost $1.5 million to construct, with the annual cost of maintenance between 2004-2007 at approximately $55,000, using mostly in-house labor (Kreith 2007). Pig fences constructed to support four pig eradication programs in California, some of which occurred more than 20 years ago and none of which were recent, were reported to cost between $22,944, and $51,282 per kilometer (Christie *et al*. 2014).

Due to the high initial cost of fencing, and additional, regular costs of fence inspection and maintenance, it is unlikely to be feasible to completely fence large properties or portions of them. It may, however, be feasible in the long term to fence relatively small areas where sensitive resources exist, especially where fencing is unlikely to be affected by erosion or windfall from trees. In such cases, this would help reduce or prevent the need for regular fence line inspection and repair.

Fencing could also be placed along Network property boundaries, to slow or prevent immigration of pigs from adjacent private properties where their presence may be promoted for the purposes of recreational hunting. If fencing is applied on a small scale, both initial costs and maintenance costs are lower, increasing feasibility. When considering the feasibility of fencing for some areas, adequate assessment of the potential impacts to native species of wildlife is needed to ensure that potential adverse effects are mitigated. Pinnacles National Park reported no adverse effects to native wildlife from the style of fence that was installed at that site (Park staff personal communication). Park staff reported that the large size of the openings in the wire mesh allowed smaller animals to go through, and the low height of the fence allowed animals such as coyotes and deer to jump over.

Fencing grant programs exist, such as the Natural Resources Conservation Service (NRCS) and the National Agricultural Conservation District (NACD), which manage the "Perimeter Fencing for Feral Swine Grant Program". This program exists to help landowners and managers install or repair fencing to limit the impact of pigs. The program focuses on areas where pigs are a risk to producers, natural resources, or communities. During 2024, the NACD administered a $7.5 million cost-share program to assist with the installation and maintenance of perimeter fencing to reduce wild pig access and impacts.

Deterrence of Wild Pigs—Several studies have been conducted to test the effectiveness of chemical repellents against wild pigs. A French study, conducted by Vassant and Boisaubert (1984), tested 25 chemical repellents and acoustic devices to deter wild pigs. The study showed that pigs became desensitized to methods applied and were generally undeterred by all repellents within a few days of deployment (Vassant and Boisaubert 1984). Additional repellents were tested and determined to be ineffective in deterring wild pig populations from designated areas (Massei et al. 2011).

Pigs are deterred by human presence and activity and have become nocturnal in areas where desirable resources exist but humans are also present during daylight hours. Hunting pressure has been documented to modify pig movements and presence, and, in some cases, pigs have been successfully pushed from within some properties into other properties due to intensive hunting pressure, some of which included use of dogs (Barrett and Birmingham 1994). This method has little validity within most management programs, as pigs displaced to properties from hunting pressure may return as soon as the pressure is no longer present. Additionally, pigs that are displaced onto adjacent properties are likely to continue breeding and could disperse into undesired areas almost continuously. This scenario can create ongoing management challenges, as these pigs may require constant monitoring and control efforts. Such continuous pressure could potentially be as costly, or even more costly, than implementing effective removal efforts in the first place. Therefore, it is crucial to manage pig populations in a way that minimizes displacement and ensures that removal efforts are comprehensive and effective, reducing the need for ongoing, costly interventions

Reproductive Control—The Gonadotropin-releasing hormone (GnRH) vaccine stimulates production of antibodies that suppress production of sex hormones (Massei et al. 2011). In a 2002 study, administration to captive female pigs of a 2000 µg (micrograms) single-dose shot was most effective in maintaining sterility during the 36-week study. Only one in nine subjects that received this vaccine gave birth during the study (Killian et al. 2004). This study, along with several others on various species have found that animals injected with this vaccine can be rendered infertile for up to 5 years (Massei et al. 2011).

Messi *et al*. (2011) concluded the advantages of reproductive control were humane and were species-specific. The disadvantages identified were that the method is slow acting at a population level, requires trapping of most of the females in the population, injection, and release with potential for high expense due to trapping effort. However, for practical purposes, if the effort required to capture the pig was expended, there seems to be little reason not to euthanize the pig rather than add the expense and risk associated with reproductive control. Due to those factors, this method is most likely not viable within most pig management programs, unless lethal removal is not possible.

Contraceptives are available and have been utilized for several species successfully and have been studied for their use in pigs. Contraceptive vaccines investigated for their use on wild pigs are divided into two groups, those containing the gonadotropin-releasing hormone antigen, GnRH, and those containing the proteins of the zona pellucida, PZP (Oliviero *et al.* 2019). One GnRH vaccine is registered for domestic pigs and consists of two injections. A general GnRH vaccine developed by APHIS NWRC, GonaCon™, is reported to be effective in a single-shot format available for multiple species, including wild pig (Miller *et al.* 2006). Studies have shown, however, that a single dose of that vaccine had a low effectiveness in White-Tailed Deer (*Odocoileus virginianus*), instead requiring a second dose (Walker 2020). Pigs that received the GnRH vaccine were documented to be in better body condition than those unvaccinated, posing possible implications for wildlife managers (Gionfriddo *et al.* 2011). Although GnRH vaccines are available via dart gun for other animal species, instances of usage on pigs were inconclusive, more likely only being deliverable through direct handling and injection of tame domestic pigs. Efficacy of GonaCon™ on an unfenced island deer population was assessed in a five-year project initiated in 2014 (Walker 2020). Walker 2020 found that the cost of a single capture averaged around $2,000 but was not successful in eliminating population growth, even though greater than half of the population estimate at the time of project initiation were inoculated.

There are few studies available demonstrating the efficacy of, or researching, PZP vaccines on wild pigs. PZP is prepared using porcine zona pellucida protein, a "self protein," making it less immunogenic if it was to be used (Miller *et al.* 2004). PZP vaccines can be injected into animals directly, or delivered by dart gun, and have been documented for their use on free-roaming horse (*Equus ferus*) and white-tailed deer populations. The price of a single, one-year dose of PZP for free-roaming horses was reported in 2012 to be $24, although this does not account for personnel or equipment costs (Kirkpatrick *et al.* 2012). Reports of PZP vaccine costs vary significantly by reporter, and only represent the version created for equine use. Both varieties of contraceptive vaccine must be administered intramuscularly, which poses no issue for domestic pigs that can be readily handled but is not feasible for wild pigs. Remote delivery via dart gun, if available, would be impractical. Factors include those shared by traditional ground hunting efforts; widespread populations dwelling in impractical areas, inability to confirm resightings, pushing populations into more distant areas, and requiring extensive resources to acquire enough personnel to effectively track and vaccinate whole sounders in single instances while pigs are active nocturnally (Oliviero *et al.* 2019).

Lethal Removal of Wild Pigs

Studies have shown that a removal rate of between 60% and 80% is necessary within a pig control program to prevent population growth (Hone and Pedersen 1980; Barrett and Pine 1981; Kreith 2007; Bengsen *et al*. 2013). It is difficult and, in some cases, impossible to achieve that level of control using only one method. Choquenot *et al*. (1993) found that an intense trapping-to-kill program can reduce populations by 80 to 90%. However, some individuals are inherently resistant to trapping or become wary of traps during trapping; therefore, trapping alone is unlikely to support effective eradication of pigs.

Whole sounder removal (WSR) has been identified as a more effective approach for reducing pig population sizes and preventing population growth compared to traditional methods. By targeting and removing entire sounders, WSR reduces the chances of survivors developing aversion to traps, dispersing, and continuing to breed. This method not only curtails the population more efficiently but also requires less personnel effort, as it minimizes the need for repeated interventions and follow-up management. Implementing WSR can lead to more sustainable and cost-effective outcomes in pig population control (Gaskamp 2021; Kilgo *et al*. 2023). Traditional removal methods, including trapping and hunting with dogs could be used in conjunction with WSR, and may be effective for removal of trap-shy individuals not captured during trapping, but does not result in the removal of as many individuals or as great of a reduction in density if used as the primary method of removal (Gaskamp 2012; Lavelle *et al*. 2021; Lewis *et al*. 2022; Kilgo *et al*. 2023; Sparklin 2009). Studies have documented that individual pigs previously exposed to trap sites, when their sounder is removed, are reluctant to approach, or entirely avoid trap sites in the future (Gaskamp 2012). During eradication efforts, a large portion of effort is often focused on the removal of the last few trap-shy individuals (Lewis *et al*. 2022). Thus, eradicating whole sounders and limiting the number of individuals exposed to removal efforts will leave less trap-shy individuals on the landscape, diminishing the amount of effort needed to remove them.

WSR is achieved by conducting enough surveillance to assess the size and composition of each sounder. This is most often done using cameras. Then applying a combination of methods to ensure that all individuals of the sounder are successfully removed. For example, if a sounder is identified and is composed of 10 pigs, four brown pigs and six black pigs (camera surveillance may allow for more specific characteristics to identify individuals), then a trap or series of traps are set to target the area where the sounder has been documented. Trapping is initiated and continued until all individuals within that sounder are captured or have been documented to avoid traps. If individuals are documented avoiding trap types employed, or bait used, the trap type and/or bait can be adjusted and trapping continued. If trapping is unsuccessful, targeted direct firearm removal, with or without the use of dogs may be applied, until all individuals from the known sounder have been removed, and WSR has been achieved.

Four successful pig eradication programs are known to have occurred within California. Three were on islands, and the fourth used fencing to create an island effect. The island effect is important, as the island effect prevents pushing pigs from eradication areas into areas of refugia during removal efforts for survivors to potentially recolonize the area where efforts were conducted previously. A pig eradication program on Santa Cruz Island, one of the California Channel Islands, utilized a combination of fencing sections of the island, trapping, ground hunting with dogs, and aircraft-assisted hunting from a helicopter to remove all the pigs from within fenced sections of the island. A second eradication program was conducted within Pinnacles National Park in California. The program at Pinnacles involved installing perimeter fencing and then cross-fencing sections of the property, followed by trapping and intensive ground hunting to remove all the pigs within each fenced section. Preventing pigs from freely moving into and out of eradication areas, and using fencing to make large areas smaller, are important facets of these programs. intensive and adaptive removal efforts were then implemented, using a suite of methods where needed, and conducting effective comprehensive surveillance to inform targeted removal efforts, and to indicate when eradication was achieved. Following successful eradication with effective maintenance of fencing or biosecurity measures to prevent new pigs from recolonizing areas where eradication was previously successful can be costly of personnel time and funding.

A fifth pig management program in California, recently reporting near eradication, was conducted on the border between California and Arizona, within the Havasu National Wildlife Refuge. The refuge is located on the Colorado River and serves as an oasis of suitable habitat for pigs, surrounded by uninhabitable desert habitat. As a result of those habitat characteristics, the movement of pigs was restricted to within the refuge, creating an island effect without relying on fencing or surrounding ocean to do so. In addition, much of the refuge is relatively open wetland habitat with little tree cover to allow pigs to hide from aircraft. Trapping was mostly ineffective within this program for a variety of reasons, and the program primarily relied on aircraft-assisted hunting, conducted twice per year during most years, to remove pigs from the refuge. The Judas pig method was used as a part of all three eradication programs in California.

Although pig eradication from Network properties may not be possible, feasible, or could take a long time to achieve, it is important to incorporate lessons learned from successful programs into the development of the Network's pig management strategy. Even though there may be differences between these systems, valuable insights can be gained from previous efforts that could inform and enhance the effectiveness of the Network's approach.

The most significant lesson from successful programs is that the use of a complementary suite of methods, when applied together within an adaptive management framework, has consistently yielded the most effective results in pig management programs. This integrated approach will allow for flexibility and the ability to respond to changing conditions, ensuring that various strategies work synergistically to control pig populations more effectively. By continuously monitoring and adjusting methods based on real-time data and outcomes, an adaptive approach would maximize the impact of management efforts and enhance the overall success of pig population control initiatives.

Trapping—Trapping has been used to capture and manage pigs since the late 1800s (Dobie 1929) and is, currently, one of the most effective techniques for removing pigs. Trapping is primarily used to gather pigs for lethal control but can also be used to capture pigs for administration of sterilization medications, collaring, data collection, or other purposes. Important elements of trapping include bait site selection, trap selection, pre-baiting, and trap monitoring. Trapping elements are described in more detail in Table 1.

Table 13. Important elements of trapping.

Trap Type	Trapping Element Description
Pre-baiting	Pre-baiting on a selected trap site should begin several days to a week before installation of the chosen trap type. Once pigs are observed consuming the bait, the trap should be set. Set-up during the middle of the day is recommended, since pig activity will be at its lowest potential (Mayer 2009). The most effective way to monitor a bait site is via cellular trail cameras (Higginbotham 2014).
Bait Types	Most effective pig baits are corn-related products. Shelled corn is the recommended bait for pig trapping, but soured corn, ear corn, corn meal, grain, fruit, and many other baits have been used with varying rates of success (Mayer 2009).
Trapping Location(s)	According to Higginbotham (2014), the ideal locations to pre-bait and set traps are at the location of damage. This could mean a damaged crop field, rooted creek beds, or any feeding locations. VerCauteren *et al*. (2020) suggests that placing the trap between damage sites and bedding locations will be the most effective.

The basic structure of traps has changed little over time, and nearly all modern traps still consist of walls, a door, and some kind of mechanism that closes the door (Hamrick *et al*. 2011, Higginbotham 2014, and VerCauteren *et al*. 2020). Trapping success may vary by time of year in some ecosystems. In the dry season (typically May-October), trapping success is likely to be higher, as acorns are not yet available (Barrett *et al*. 1988). When the native food sources (i.e., acorns) are in low supply, and supplemental food sources, such as agricultural crops, are not available, baiting pigs to trap sites may be accomplished with less effort (Higginbotham 2014). Common pig trap types include corral traps, drop traps, and box traps. Those traps are described in more detail in Table 2.

Table 14. Common trap types.

Trap Type	Trap Type Description
Corral Traps	Corral traps are usually circular, “teardrop”, or “football” shaped with a gate on each end (Hamrick *et al*. 2011). They are typically preferred when dealing with a large population of pigs, due to greater size and ability to trap multiple pigs at once (Williams *et al*. 2011). Previous studies have found that the use of portable corral traps resulted in 2-5 hours of work per pig removed (Coblentz and Baber 1987) and captured roughly four times more pigs than box-style traps (Williams *et al*. 2011). The recommended professional sized coral trap consists of 6-10 galvanized panels, 15’ – 20’ x 5’ tall in length, using 4” x 4” mesh secured to T-post driven into the ground around the perimeter of the trap (Higginbotham 2014 and VerCauteren *et al*. 2020).

Trap Type	Trap Type Description
Drop Traps	Drop traps are designed and function similarly to corral traps, but are suspended in the air when set, rather than placed on the ground. The assembled trap is lifted about 1 m from the ground, allowing pigs to move underneath the trap from all sides to access the bait, and can be attached to posts or surrounding trees (VerCauteren *et al*. 2020). Instead of using a door mechanism, the entire trap is dropped once the targeted group of pigs have all entered the trap. According to VerCauteren *et al*. (2020), drop traps eliminate "gate shyness," a behavioral attribute that may prevent some pigs from being captured in traps with gates.
Box Traps	Box traps are significantly smaller than corral traps and primarily used for targeting individual pigs (VerCauteren *et al*. 2020). Most box traps are designed to be transported in a standard truck bed, with the common dimensions being 1.22m x 1.22m x 4.44m (VerCauteren *et al*. 2020).

Trap gate designs vary and are an important component of trap construction. Gate designs include passive, guillotine, saloon, and rooter styles. Higginbotham (2014) described eight categories of gate activation. Those include human-activated, no trigger, tripwire trigger, pressure plate trigger, trough trigger, rooter stick trigger, bucket trigger, and tire trigger. Those trigger types are described in more detail within Table 3.

Table 15. Trap gate types and descriptions.

Gate Type	Gate Description
Passive Gate	Passive gates are designed to allow pigs to enter by pushing through the gate with their snouts. During the pre-baiting phase, the two trap panels that make up the gate are disengaged from the trap actuation spring, allowing the doors to remain open once pigs have entered the trap (VerCauteren *et al*. 2020). After the pigs become accustomed to feeding within the trap, a spring is added to one of the panels that will snap it closed once a pig has entered (VerCauteren *et al*. 2020).
Guillotine Gates	This type of gate is set vertically above the trap opening and once activated, drops straight down. Guillotine-style gates can be triggered by the pigs themselves or by human-activated remote controls (VerCauteren *et al*. 2020).
Saloon Gates	Saloon gates are attached to the side of the trap opening, are spring loaded, and swing closed once activated.
Rooter Gates	Generally constructed of tubular steel with three side-by-side sections in a one-meter-wide gate (Mapston 2004). Rooter gates are activated once pigs are inside the trap, sometimes using a trigger system to close the doors, but once closed allow additional pigs to enter the trap. Rooter gates are typically wired open during the pre-baiting process (VerCauteren *et al*. 2020).

A variety of trap-trigger types have been developed to release different kinds of doors on pig traps. Some examples of trap door trigger-types are described in more detail in Table 4.

Table 16. Trap gate-trigger types and descriptions.

Gate-trigger Type	Gate-trigger Description
Tripwire Trigger	Uses a string or wire set to release the gate once a pig moves it. This trigger can be more cost effective than using human activation but can be activated by non-target species and typically doesn't result in capture of the entire sounder at once (VerCauteren *et al*. 2020).
Root Stick Trigger	This trigger uses a string attached to a stick, placed inside of a bait pile. This method is used to reduce potential for non-target animal activation since the trigger mechanism is buried within a pig-specific bait pile that is unlikely to be triggered by anything but a rooting type behavior within the bait pile.
Tire Trigger	Bait is placed inside a tire that is attached to the activation string. The idea behind this trigger is that only adult pigs will be strong enough to pull the tire and activate the door of the trap.

Gate-trigger Type	Gate-trigger Description
Human-activated Trigger	Human-activated triggers range from a person hiding in a blind with a string attached to the gate, to different types of remote activation. Remote activation triggers range from line-of-sight remote activation to remote monitoring and activation using cellular cameras to monitor for pig presence with cellular-activated mechanisms that release the trigger from a phone or computer (VerCauteren *et al*. 2020).

Snaring— Snares are a type of trap but differ from other traps in some ways, and therefore are described separately. Snaring is a very old method of trapping animals, but only effective at removing individual animals (Bateman 1973, Mayer 2009). The cost of snares is far lower per trap when compared to other trap types (Mayer 2009). However, the use of snares is controversial, especially neck snares, due to the potential for slow strangulation (Kaser 1993 and Mayer 2009).

Snares are composed of a flexible wire cable arranged in a loop, with a sliding "lock" that tightens to hold the animal when the animal pulls against the loop (VerCauteren *et al*. 2020). Snares can be set under fences, on trails, or on trees that pigs use as rubs (VerCauteren *et al*. 2020). The cables can be set as neck snares or foot snares and, if checked daily as required by law, most non-target captures can be released without major harm (VerCauteren *et al*. 2020). This method should not be used in areas where potential nontargets include listed or protected species, as removing an animal, such as a mountain lion or bear, from a snare safely, would likely require the use of anesthesia drugs. Snaring also has a higher potential for capturing domestic non-target species, pets or livestock that can lead to serious injury or death (Littauer 1993, Mapston 2004, and Mayer and Brisbin 2009).

Ground Hunting—Recreational hunting alone has been documented as ineffective for long-term control of wild pig populations (VerCauteren *et al*. 2020). To reduce a wild pig population effectively, within a management program, 60-80% of the total population needs to be removed to outpace population recruitment from high rates of reproduction and immigration. Mayer (2014) reported that recreational hunting may remove an average of 23% annually.

However, ground hunting by professional, contracted hunters has been used to effectively reduce pig populations, especially when performed in conjunction with trapping efforts. Effective ground hunting is labor intensive, and, as a result, can be costly to conduct necessary scouting to support efficient removal. The level of ground hunting effort needs to be high to be effective and should target areas, times of day, and times of the year when hunting will be most effective. These efforts should be well planned and carried out, with tactics, training, and discipline employed to avoid "educating" pigs through failed removal efforts. Such failed attempts (i.e., missed pigs) could impede future management efforts, and, if attempted removal is tied to human presence/scent, could reduce the effectiveness of other removal techniques.

Centerfire rifles with calibers in .270 or larger and shooting moderate to heavy weighted bullets (>130 grains) are recommended for removing pigs via firearm (Mayer 2009). Shotguns, in 12-gauge or larger, can be used with buckshot or slugs in areas with heavy timber, brush, or general cover (Mayer 2009). Directly targeting juvenile and adult sows should result in significantly lower population growth rates, thwarting population recovery following removal efforts (White and Kunkel 2016). High adult male mortality rates typically don't have a significant effect on population growth rates (White and Kunkel 2016).

Wild pigs are primarily active at dawn and dusk, but human presence, especially removal efforts conducted during the day, can cause pigs to be more active nocturnally. The use of night-vision and thermal optics to hunt pigs at night, has greatly increased the success of removal via ground hunting (Mayer 2009). Shooters working at night must be well trained, as shot placement is important, and safe shooting can be more complicated at night. The logistics and feasibility of night hunting are specific to each property and location dependent. Ground hunting of pigs at night may be more desirable within urban or public properties, which may be void of public presence at night, and where legally allowed, reducing public safety concerns and the potential for visitors to witness or hear evidence of lethal pig removal efforts.

Aircraft-assisted Hunting—Aircraft-assisted hunting can be effective in areas with open landscapes and sparse cover, where pigs are easily viewed and cannot hide from aircraft. This approach can decrease the targeted population by 65-80%, making it a powerful tool for quickly lowering numbers. By significantly reducing the population early on, aerial shooting can set the stage for other management techniques to be more effective in maintaining lower pig numbers over time (Hone 1990, Saunders 1993), which would be necessary for total eradication (Sharp 2012). Although the costs of aircraft hours can be high, this approach could result in lower cost per pig removed when compared to other methods. However, this technique has been met with strong public opposition when proposed as a part of wildlife management programs in California, all, or nearly all, of which resulted in aircraft-assisted hunting being removed from the list of methods employed. Due to the human uses of Network properties, the proximity of most properties to urban areas, and the sensitivity of the public within the Bay Area, it is unlikely that this method could be used as a part of pig management efforts here.

Ground Hunting with Dogs—Hunting dogs can be used to locate and capture pigs, and this method has been used successfully during the latter stages of eradication programs for locating and removing the last pigs that remain within a given area (Choquenot *et al*. 1996, Dickson *et al*. 2001). The success of using dogs for wild pig management largely depends on the training and skills of both the dogs and the hunters/dog handlers (Mapston 2004, Choquenot *et al*. 1996, McIlroy and Saillard 1989). This technique usually results in only 1-2 pigs captured per event (Caley and Ottley 1995). Caley and Ottley (1995) found that hunting dogs were successful in catching or cornering solitary pigs about 88% of the time, but that number rapidly declined when the encountered group size increased. Although this method can be effective when used in concert with other methods, it should not be the primary management method and is best used as a part of a multi-method management effort, especially for large-scale projects (Choquenot *et al*. 1996, Caley 1999). The use of hunting dogs for pursuing pigs is regulated by the CDFW and should not be conducted without a strong understanding of those regulations. This technique, in California, has also been met with public opposition and is argued to be inhumane for animals pursued.

Judas Pig Method—The Judas pig method is a wildlife management strategy used to assist managers in locating and targeting new sounders or sounders that are difficult to locate or target. This method includes capturing a group of pigs and euthanizing all but one of the pigs captured. Preferably, the remaining pig, or “Judas”, selected is an adult sow, thus increasing the potential that the Judas will find a new group of pigs and easily integrate into that new group. The pig selected to be the Judas is immobilized, fitted with a GPS collar, and released (Sweitzer and McCann 2007). The Judas will eventually find and join a new group of pigs, which can be tracked and targeted using the GPS data from the Judas. If the Judas pig dies, the collar falls off, or other factors render the collar or pig incapacitated, a new Judas pig should be selected to replace it (Wilcox *et al*. 2004). Within an ongoing management program, use of the Judas pig can help to locate and target the smaller groups of pigs that have avoided capture using other methods (Mayer 2009) and can be used as a valuable part of a comprehensive program.

Toxicants for Pigs—Poisoning of pigs has been widely effective as a control method in other countries (McIlroy *et al*. 1989, Saunders *et al*. 1996, Choquenot *et al*. 1996). However, risks to non-target species, from either direct or indirect consumption of baits infused with toxicants, are difficult to control. Pigs that consume poisoned bait may vomit part or all the bait up after consumption, resulting in the excreted bait being available to be consumed by non-target animals. Pigs that vomit may not consume a lethal dose of the bait, which may result in those individuals becoming averse to the bait type and, thereby, reducing the effectiveness of the poisoning program. Carcasses of pigs that are killed by poison baits that are not able to be recovered, may cause secondary poisoning of carnivores or scavengers that are unintended targets. Poisoning could also potentially harm domestic animals and even people. These dangers arise if baits or carcasses containing poison are accessed, or if hunters unknowingly kill an animal that has been poisoned but has not yet died from the effects. Such scenarios underscore the need for strict precautions and careful management when using poisons, in wildlife control, to prevent accidental poisoning and ensure the safety of non-target species and humans. No toxicants are currently registered and legal for use on pigs in the US. Due to the many complications associated with a poisoning program for pigs, it is unlikely to be a viable option for control of pigs within Network properties.

Public Sensitivity to Lethal Removal—Public perceptions towards lethal management vary by background and experience, and in California, animal welfare issues may be more heavily scrutinized than in other states. Additionally, non-lethal management options are always considered first with lethal control conducted only as a last resort, due to ethical considerations. To avoid negative reactions due to public sensitivity, significant effort must be made to prevent any direct or indirect exposure of the public to lethal pig management activities. This includes carefully planning and carrying out management operations in a way that minimizes the visibility of such activities. The goal is to conduct necessary population control measures while maintaining a level of discretion that protects the public from witnessing or encountering any evidence of lethal actions taken against pigs. This approach helps to balance the need for effective management with public concerns and ethical considerations.

Section 10: Pig Management Program Development and Adaptation

A wild pig management plan should be strategically designed to address the population ecology of pigs on Network lands. This involves carefully considering the frequency, location, and types of management techniques used, as well as determining the specific level of population reduction needed to meet both short-term and long-term objectives. Information such as adult and juvenile survival, adult and subadult sex ratios, population age structure, variation in population growth rates, etc., affect the amount and frequency of pig removal necessary to achieve program goals. With known data for these parameters, population modeling can be performed to more accurately identify the number of pigs that must be removed to achieve program goals.

By utilizing a multi-faceted approach where different control techniques are implemented, when and where they are most effective and efficient, the Network's wild pig management programs can maximize probability of success. Application of a complimentary suite of methods, used in concert and applied in an adaptive management framework, have been proven to yield the greatest results within pig control or eradication programs.

Although this Plan was developed to focus on management within Network lands, some consideration was given to the areas outside of and near these properties; however, within the scope of this effort, there were not enough resources to support a complete assessment of pig activity in these adjacent areas, which could be important for maximizing the effectiveness of future pig management efforts. The design of the pig management program and associated efforts within Network properties should focus on identifying or creating "islands" or isolated areas where pigs can be specifically targeted and removed. This approach mirrors the strategies used in successful eradication programs, which have effectively used isolated areas to eradicate pig populations. By concentrating efforts within these defined areas, it becomes easier to manage and monitor pig removal, reducing the likelihood of reinfestation and increasing the overall success of the program. Some islands, or partial islands may already exist within the Network in the form of divisions created by dense urban development and large freeways. Smaller islands could be created within those larger islands by using fencing, where feasible, and through intensive pig removal efforts, informed by effective surveillance/monitoring efforts. These islands should be developed based on the location of identified priority areas within each property, cluster of properties, and with consideration to the Network as a whole.

Pigs are the most invasive species in the world, their distribution has grown in the U.S. and in California. The negative impacts of pigs on the landscape are well documented. The limited data available regarding the historic pig management effort within Network properties indicate that the effort has not sufficiently controlled growth of the pig population within Network properties, and the greatest amount of growth has occurred during the last five years. With sufficient food and habitat resources available, pig population growth within Network properties and within the region may quickly require a significant increase in pig management resources to prevent significant damage to sensitive resources that may be unaffected within Network properties currently. More comprehensive data are needed to effectively guide development of an adaptive, maximally efficient, and fiscally responsible pig management program.

In the following sections of this Plan, the current pig management program is reviewed in detail. Specific recommendations are provided to help guide the development of a more effective and comprehensive program. These recommendations aim to address the challenges and opportunities identified in the existing approach, offering strategies to improve the program's overall effectiveness in managing pig populations and protecting valuable resources within Network properties.

Evaluation of Historical Pig Control Efforts

Pig population control has not been conducted for the same length of time within all Network properties, or for all partner organizations. For some organizations and properties, removal data indicate that work has been and continues to be conducted primarily by one contracted entity since at least the 1990s. The number of partner organizations and the number of properties that the contractor provided pig removal work for has increased since the 1990s.

Based on personnel interviews, the pig contractor is very skilled, responsive, and works quickly to put pig management in place, despite limited personnel and a very large area to cover. When pig damage or pig sightings are reported to the pig contractor by partner organizations and land managers, those reports are investigated. Although the priority of some reports requires more immediate response, in general, all reports receive the same level of attention, with most, if not all, responses resulting in subsequent trapping efforts. Based on personnel interviews, primarily one trapper conducts all pig management within all Network properties simultaneously for the duration of contracted services. Additional help was occasionally provided from up to two more personnel to move traps within or between properties, but trapping is mostly conducted by one person. When pig activity was high and the primary pig trapper was not available, a replacement trapper was used; however, the level of trapping effort was not increased. Detailed data on the level of effort expended during pig removal work are not recorded or reported to Network organizations. Instead, monthly invoices reflect consistent totals, derived from the overall annual budget for each contract. As a result, there are no records of hours worked, making it impossible to calculate or compare removal efforts, such as the number of and cost per pig removed, per hour, per month, or per year of effort. Such information would be beneficial for evaluating and improving the program for the future based on performance metrics.

The primary method for pig management within Network properties has been trapping for lethal removal, although some pigs were removed opportunistically via firearm when encountered in areas where a safe shot was possible. Dogs have been used to track individual or small groups of pigs for removal in some situations, although infrequently, and the exact circumstances that prompted the use of dogs were not identified. At least one corral trap has been used, but this trap type was set infrequently. The primary trap type used is small cage traps, constructed of angle iron and hog panels, with a rooting-style door attached to a rooting stick. Traps were generally small enough to fit in the back of a pickup truck, approximately 8'L x 4'H x 4'W, for ease of transport. Traps were most often placed along roads, and always within an area that could be accessed by a truck or Utility Terrain Vehicle (UTV) to assist with moving traps and to increase efficiency of baiting and checking traps. Pig trapping was generally conducted by placing fermented corn in areas where pigs have been detected before, where pigs were detected and reported to the pig contractor, or where pigs were directly observed by the pig contractor when traveling roads by vehicle (truck during the dry season or UTV during the wet season).

Effective decision-making within a pig management program involves considering various factors, particularly when aiming to reduce the overall population. However, the lack of a defined prioritization hierarchy within Network partner organizations likely led to some trapping efforts being focused on low-priority pigs. If this occurred, the effort expended on removing these low-priority pigs would have diverted resources away from more critical, higher-priority pig management tasks. Given that only one person was available for this program, misallocation of effort could have impacted the program's overall effectiveness, underscoring the importance of clear prioritization to maximize resource use and maximize pig population control for the Network as a whole.

Quality data collection and frequent evaluation are crucial for prioritization within an adaptive management program, ensuring that removal efforts are focused and maximized for desired impacts. Data such as sex, age, and reproductive status of pigs captured should be recorded following established protocols to ensure that they are science-based and that assessments are consistent over time to ensure they are comparable. Every time a trap is placed, a bait station is baited, or either a trap or bait station are checked, data regarding the number of pigs, the age, reproductive status, and a physical description of the individuals captured or visiting the bait site should be recorded. The number of nights that traps and cameras are baited and active should be recorded. Training materials should be developed to ensure that all personnel are collecting pig control-related data in the same ways. Training materials could be in the form of brochures, conducted in-person or provided virtually. At a minimum, one initial comprehensive training should be required of all personnel that are conducting pig control work. If relevant, refresher or updated training should be required of pig management personnel to ensure maintenance of quality data collection, and as new data collection elements are added to the program. If issues are found within the data during review, follow-up conversations and additional training should be provided to personnel that are having issues following data collection protocols. Program data should be reviewed regularly, as feasible. Other data, such as trap coordinates, trapping effort, trapping success, and observations of pig sign, damage, and baiting should also be recorded for evaluation of trends and as measures for success over time. This information, combined with an understanding of pig activity in proximity to priority areas, should guide and refine management efforts. While these data collection requirements may initially reduce time available for active pig removal, the improved strategic allocation of time and resources possible thorough analysis of high-quality program data is expected to enhance the overall effectiveness of the program. By making informed decisions based on comprehensive data, the program can better focus efforts, ultimately leading to more successful programmatic outcomes.

One person providing pig removal services over tens of thousands to possibly a hundred or more thousand acres, has likely reduced effectiveness of pig population control, regardless of personnel experience and work ethic. Additionally, without a pig monitoring/surveillance system in place, there are no clear objectives that can be identified for a response, meaning achieving WSR is unlikely, and the potential for educating pigs is increased. Despite year-round trapping efforts, pig removals have substantially increased within Network properties during the history of the pig removal program, indicating that the current population control program is insufficient. A focused, well-planned approach is needed to ensure maximum efficiency, and to reduce the number of pigs that need to be lethally removed over time, while also providing adequate protection for sensitive natural resources, protecting human use of Network properties, and the human water sources held within Network properties. Reducing the number of pigs that need to be lethally removed over time through a maximally efficient program will be the most ethical and responsible approach to managing this invasive and damaging species.

To accurately evaluate and enhance current pig management efforts, new approaches and strategies are needed. This includes shifting or intensifying efforts in different locations and times, and implementing innovative methods to increase efficiency, such as using cameras for monitoring and collecting data to support a more informed and targeted approach. Additionally, utilizing GPS collar data to better understand pig movements can provide valuable insights into their behavior and habitat use. These advancements will help refine the program by allowing for more precise targeting, and better evaluation of methods applied, ultimately leading to more effective management of pig populations.

Regional Collaboration and Coordination

To support regional collaboration and coordination, data formats (i.e., databases) and data collection protocols should be standardized, allowing for data to be more easily combined, so that trends and results may be evaluated regionally, with a feasible amount of effort. Data collected should include all pig observations, damage detected, removal effort (by type of effort, trap-type, location, etc.), removal success (captures per trap night), and details regarding pigs captured (i.e., age, sex, reproductive status, genetic lineage or variety, etc.) following standardized protocols. Data should be combined and evaluated at least quarterly, with collaborative meetings between landowners, and other stakeholders, scheduled at least annually to discuss successes, challenges, and priorities for the next year of effort. A standardized annual report summarizing pig management efforts should be drafted, and pertinent results of those efforts should be discussed during collaborative meetings.

The land use practices in place within properties adjacent to Network properties should be investigated and evaluated if possible, and the Network should attempt to meet with landowners to discuss shared pigs, pig conflicts, and pig management efforts. During collaborative meetings, common and conflicting goals should be identified. If adjacent, non-Network landowners are promoting presence of pigs on their properties for hunting or other reasons, shared boundaries may be a priority for fencing or for concentrated pig surveillance and removal efforts.

Translocation and release of wild pigs is thought to have occurred within California to supplement guided hunting operations, and this has helped pigs spread to new areas within the state. The Network should work collaboratively with law enforcement from CDFW, or other pertinent agencies, to help monitor for and prevent additional introductions or supplementation of the pig population on properties adjacent to Network properties.

Steps to consider for developing Network collaboration and synthesizing efforts to improve management of pigs in the region:

1. **Each Partner Organization**:
    a. Identify and list priority properties, resources, and areas to protect from pig damage, and rank each one.
    b. Identify specific threats from pigs and management goals for each priority property.
    c. Identify specific steps, resources, and a timeline for achieving each of those goals.
    d. Identify and target pig travel routes, refuge areas, and known hot spots for activity.
    e. Identify suitable "check-in" intervals and schedule meetings to discuss successes and challenges and to make any adjustments needed to best support achieving goals within established timelines.
2. **Within Network:**
    a. Identify goals for pig management within each LU, and in the Network as whole, and place in short- and long-term categories.
    b. Identify how Network goals are congruent with the goals of each Network organization.
    c. Identify specific steps and a timeline to work towards achieving each of those goals.
    d. Meet at least annually to exchange management "lessons learned" among land managers and landowners in the region and share relevant data.
    e. Identify non-Network properties that may be refugia for pigs. Reach out to landowners of those properties and meet to discuss pig conflict management. Identify shared goals and conflicting goals. Discuss ways to help achieve shared goals together and ways to minimize impacts of conflicting goals (i.e., fences).
    f. Promote future restoration techniques for priority areas and ecosystems that have been impacted by wild pigs.
3. **Outside of Network:**
    a. Identify prominent landowners with properties adjacent to or near Network properties that may also be affected by pigs and share at least some of the Network's goals for population reduction.
    b. Discuss land management practices with those landowners and the shared challenges and goals. Also identify conflicting goals and practices.
    c. When landowners are cities, it is important to discuss each city's resources and efforts for pig management to identify opportunities for collaboration, so pig management programs are aligned and that resources are pooled where appropriate and possible, helping to reduce costs and avoid duplication of effort.

<u>Identifying and Ranking Priority Areas for Pig Management</u>

Each partner organization should identify and classify primary and secondary priority areas for protection from pig damage, to establish where pig population reduction efforts should be allocated. Human health and safety should be considered when identifying priority areas and identifying whether there is potential for direct threat (e.g., attacks) or indirect threat (e.g., spread of disease, water contamination, etc.), when relevant. Primary priority areas should be those of highest ecological value and those that are also at high risk from pig damage (e.g., riparian areas or ponds that are home to listed species). Priority areas should be identified by the sensitivity of the habitats contained within each and the density and sensitivity of listed species or resources (e.g., water) contained within each. Within these, areas with the highest pig habitat suitability should be prioritized.

Secondary areas or habitats should be those that are of high ecological importance but deemed less vulnerable to pig damage than priority areas. Additional considerations should be given to areas that are likely to be source populations to replenish the pig population following removals efforts. These may be areas where pigs exist within Network properties, such as access points where pigs disperse into private properties or urban areas. A Network-wide strategy should be developed with the intention of managing all areas within as a collective unit. A similar process as referenced above could be applied, beginning with each LU, to identify management priorities areas within each.

<u>Low-effort and Sustainable Monitoring for Wild Pigs</u>

Improved, low-effort monitoring can be achieved by better organizing and capturing the information that is already being observed and reported by Network staff and contractors and storing it in more usable formats. Network properties already have "boots on the ground" in the form of Network organization staff, public users, lessees of Network properties, and contracted pig management staff. These individuals are already conveying valuable information, often by phone or email, but much of this data is not being systematically captured in databases. As a result, there is limited ability to efficiently track reported information, or the management actions taken in response, and the outcomes of those actions.

To enhance monitoring and management, a system is needed within each organization that can capture and organize this information effectively. Each organization’s data management system should be standardized with those used by other Network organizations to ensure seamless data sharing and collaboration. Such a system would support improved tracking, analysis, and coordination of pig management efforts across the Network, ultimately leading to more informed decision-making and more effective pig population control.

To effectively monitor pig population growth and movements within and near Network properties, it is essential that all pig sign, damage, sightings, and removals be recorded in a standardized and congruent format and be georeferenced to support mapping and spatial tracking. Data collection systems should be developed to facilitate efficient data entry by Network employees, recreational public users, and tenants who utilize Network properties.

While the outputs should be consistent, the data collection methods do not need to be identical across all user groups. As long as the forms include common fields that can be easily integrated, the systems can vary in complexity. For example, the data systems used by Network employees and pig removal contractors should include more detailed fields and be more extensive, reflecting their specialized roles. Meanwhile, systems designed for use by the public or lessees of Network properties can be simpler, focusing on essential data fields, to encourage participation and ease of use. This tiered approach ensures that all relevant data is captured while accommodating the different capabilities and roles of each user group.

Network Employees—To enhance the monitoring of pig populations within Network properties, all Network employees and contractors who work within or visit these properties, particularly those who regularly go into the field in areas known to have pigs, should have basic training to collect data using customized data entry forms. These forms should be designed to streamline the collection of high-quality data, minimizing the burden on employees and preventing interference with their other duties. Mobile applications like ESRI’s Field Maps or Survey123 can be utilized for this purpose, with Field Maps recommended. These applications allow for efficient and accurate data collection, even in the field. Protocols for data entry should be developed, and employees should be provided basic training to identify pig sign and damage, and to enter the associated data into digital forms while following protocols.

To ensure reliable data collection, all field staff should have access to digital data collection through Network-provided devices, such as tablets or smartphones. These systems should be designed to function offline, accommodating work in areas with little or no cellular service. By equipping staff with the necessary tools and training, the Network can ensure consistent and high-quality data collection across all properties, which will support more effective pig management and monitoring efforts.

Park Users or General Public—To facilitate public participation in pig data collection, a user-friendly data collection form should be designed that can be downloaded as a table or spreadsheet. This form should have data fields organized in a way that is copy-and-paste compatible with the database generated by the Network employee data system, ensuring seamless integration of public-contributed data. The form should be implemented within a publicly available and widely used application, like iNaturalist, which is already popular among outdoor enthusiasts. By using a common application, especially one that park visitors may already have on their personal devices, the likelihood of participation in pig data collection efforts increases. If a pig-specific application were required, it would likely deter park visitors from contributing, as they may be less willing to download and use a new app.

To further encourage participation, trailheads at parks could feature signage with QR codes that link directly to brochures describing the pig population tracking program. These brochures would encourage park visitors to participate by explaining the importance of their contributions. Additionally, the brochures, whether accessed through iNaturalist or via QR code on signage, should include a guide on "how to identify pig sign and pig damage." To enhance this initiative, a short informational video could be developed, demonstrating how to identify pig sign and record relevant pig data. This video could be made available through QR codes on signage, posted to social media, and hosted on Network websites. By making the process as accessible and engaging as possible, the Network can harness the power of citizen science to improve pig management and monitoring efforts.

Tenants of Network Properties—About 86,000 acres of EBRPD properties are licensed for grazing (EBRPD personal communication), and other Network properties may have other tenants, with those tenants likely to see pigs and their sign on a recurring basis. The effort to harness pig presence information from Network property tenants could garner valuable pig population tracking data. Within the current program, some Network tenants already contact the pig management contractor to report sightings, but information gained from those reports is not recorded and cannot be tracked or evaluated to inform and improve program trajectory. If Network tenants cannot utilize the same data input systems as Network employees, or do not have the ability to collect data digitally, then a "Pig Reporting Hotline" could be created.

The "Pig Reporting Hotline" should be linked to a cellular phone capable of receiving texts and georeferenced dropped points. Tenants can use this hotline to report pig sightings, signs, or damage by either texting or calling in their observations. Tenants should be encouraged to provide their name, contact information, and any relevant details about their observations. If they can drop a point for georeferencing, this location data, along with the provided information, can be added to a database by the Network's designated hotline representative (e.g., employee or volunteer). This information should then be forwarded to the pig contractor for action. The pig hotline should be monitored at least daily. Voicemail messages should be promptly transcribed into the database system upon receipt to ensure that all reports are accurately documented. The pig contractor should also be able to text the hotline to confirm whether a reported location was investigated. This response should be recorded in the database to ensure that the outcome is documented and to prevent duplication of data, as the contractor should be recording data during each investigation within a digital data collection system (i.e., Field Maps). This system will help document more incidents and associated responses.

Camera Monitoring—Incorporating camera monitoring, particularly using cellular-transmission capable cameras where cellular service is available, into pig monitoring and management efforts can significantly enhance the amount and type of information gathered. These cameras can provide early detection of pig presence, monitor the number and composition of pig sounders, track visitation of bait sites, and observe pig interactions with traps (i.e., instances of avoidance). These data are invaluable for informing management strategies. Cameras should be strategically used to identify the size and composition of sounders, allowing for WSR to be pursued. With this approach, if any individuals are identified as avoiding traps, they can be specifically targeted using other methods (e.g., ground hunting or hunting with dogs).

For long-term population monitoring, camera trapping arrays should be designed, tested, and implemented. These arrays should operate for a minimum of ten days each, once per year. During the initial three to five years of program development, these camera arrays should be deployed at least twice per year to gather sufficient data and refine the management approach. Camera array surveys should be scheduled ahead of suspected breeding periods. By identifying, evaluating, and targeting the number, location, and composition of sounders before breeding, focused removal efforts can be more effectively planned and executed. This proactive approach will help reduce population growth and manage pig populations more effectively over time.

Aerial Surveillance

Utilizing a drone equipped with a thermal camera, particularly during nighttime when pigs are more active, could significantly enhance the understanding of pig activity and improve management efforts. The data collected from drone surveys can be instrumental in several ways:

- **Improved Surveillance:** A drone can be sent to conduct surveys in areas that are not easily accessible, or that would require a substantial amount of time to survey on foot. They can also be flown high enough to help reduce the potential for disturbance, increasing the potential for whole sounder detection. They can help identify pig activity in real-time, offering insights into where pigs are congregating and how they are moving across the landscape. This information can be used to refine the placement of trail cameras, ensuring they are positioned in areas with high pig activity to maximize the effectiveness of pig surveillance.
- **Determining Sounder Size and Composition:** The thermal camera on the drone can detect the heat signatures of pigs, allowing for accurate estimation of sounder size and composition. These data are critical for planning WSR and other management strategies.
- **Informing Targeted Trapping and Removal Efforts:** The data from drone surveys can be used to identify optimal locations for placing traps or planning firearm removal efforts. By understanding where pigs are most active, management teams can focus their efforts more precisely, increasing the chances of successful captures or removals.

By integrating drone technology into the pig management program, the accuracy and efficiency of surveillance, trapping, and removal efforts can be significantly improved, ultimately leading to more effective control of pig populations within the targeted areas.

In addition, the East Bay Parks Police Department already fly routine patrols over some properties and has a variety of excellent cameras to aid their duties. During routine police patrols, if pigs are observed, coordinates of pigs observed and basic information could be recorded and provided to appropriate Network organizations, if feasible and willing to do so. If possible, police helicopter pilots could be given access to the Field Maps or Survey 123 applications and trained how to enter pig observation data directly.

Fencing

The feasibility of fencing should be explored as a means of protecting particularly high-value areas by excluding pigs. In situations where full fencing is not possible, partial fencing could be strategically placed to limit pig immigration. For example, runs of fencing could be installed across identified travel routes between high-density pig areas and high-priority areas needing protection. Concentrating pig removal efforts at the ends and along the sides of these fences, where pigs are likely to be, could increase the efficiency of these efforts. By creating physical barriers and focusing removal activities in these targeted zones, the overall effectiveness of the management program could be improved.

To facilitate this, priority areas for protecting resources from pigs should be compared to movement data from GPS collars placed on pigs. Areas that are potential population sources and travel corridors should be compared to locations of priority areas and a plan to exclude or impede movement of pigs to priority areas using fencing developed. Areas that would benefit from fencing should be mapped, ranked in priority, and each area or segment of fencing evaluated for feasibility. For example, areas with dense tree cover, with frequent erosion, and areas where fencing would need to cross creeks or rivers may require more frequent fence maintenance. Pig-proof fencing should avoid such areas if and where possible. Where high priority areas for fencing overlap with existing cattle fencing, the cattle fencing should be upgraded to exclude pigs. This effort could be coordinated with necessary maintenance or replacement of cattle fencing, to reduce costs of installing pig-proof fencing. All pig-proof fencing installed should be inspected on a regular basis for damage that may allow pigs to circumvent the fencing. When areas of fencing that require repairs are identified, they should be repaired quickly. If the pig exclusion fencing runs through wooded areas where erosion from storms or falling trees may compromise pig fencing, personnel resources must be scheduled to inspect the fence and to conduct necessary fence repairs following each storm that could compromise the fence structures.

Satellite Tracking of Pigs

Placing satellite (GPS) collars on pigs will help to illuminate movement patterns in space and time, identify refugia used by pigs that may provide continual refill of pigs removed from priority areas, help identify travel routes used within and between properties that may be targeted for management, assess survival and other necessary population metrics for pigs within Network properties, assess changes in movements or land use in response to applied management strategies, to be used on Judas pigs, and help pig management staff locate and remove targeted, and especially elusive, sounders.

To enhance pig management within Network properties, an initial pilot collaring study is recommended. This study aims to gather baseline information regarding pig movements and habitat use and evaluate the potential effectiveness of the Judas method. The importance and value of collaring may vary depending on the specific goals, location, and property type of each partner organization involved in the program. For the initial collaring, it is recommended to capture and collar a minimum of five pigs, with a goal of collaring up to ten pigs for more robust data collection and evaluation. One to two collars should be deployed within each of the prospective areas. Collars should be deployed in areas with a history of pig removal and conflict, especially where past efforts have identified hotspots for pig activity.

Prospective areas for collar deployment should be prioritized based on a few key factors:

- **Proximity to Sensitive Resources**: Areas near sensitive resources that require protection from pig damage should be prioritized to prevent future harm.

- **Proximity to Refugia**: Thick, dense areas of habitat that may serve as refugia for pigs and potential sources of population refill should be targeted to monitor pig movements and population dynamics.
- **Proximity to Property Boundaries**: Areas where significant pig removals have occurred, especially near property boundaries shared with other Network or non-Network entities. Pigs may travel between properties, and identifying such access points may help guide management efforts (e.g., trapping, fencing, etc.). To maximize population reduction, adult female pigs should be targeted to allow them to join new sounders more easily and better inform pig managers regarding locations of refugia and travel routes used by those sounders. Juvenile pigs grow too quickly to place collars on them. Adult male pigs are typically solitary, reducing the benefits of satellite tracking those individuals for population level management.

Capture and collaring of pigs could possibly run concurrently, as a part of currently funded pig trapping efforts, to reduce costs associated with capturing subjects. Historic pig removal has been conducted using primarily road-based trapping to maximize the ability of one pig trapper to cover as much ground as possible. Since the number of pig removals within the Network is increasing, despite removal efforts of pigs, it is likely that pigs remain within areas of refugia, which may act as continual sources to refill areas where pig removals have been conducted. To better understand refugia and use of refugia, collaring candidates should be targeted near areas where refugia are suspected. These areas are likely to be thick habitat, in canyon bottoms or hollers, away from regularly traveled roads and trails. To accomplish this, a specific and targeted trapping effort may be necessary to capture and collar study subjects that will best support answering study questions.

There are many companies that make satellite devices for tracking wildlife. Tracking devices used for pigs are typically attached to collars but can also be attached to ear tags, implanted vaginally, or surgically placed within the body cavity. Transmitters can use several types of satellite communication signals, transmit via cellular networks, and send VHF frequencies to allow for real-time location of transmitters. The capabilities and the manufacturer of the transmitters affect the price of each unit.

Chemical anesthesia is recommended for safety (for pigs and human handlers) and for humane collaring of pigs. Controlled drugs, necessary for anesthesia and safe monitoring of collared subjects following anesthesia, are best conducted by a qualified veterinarian. In some cases, qualified wildlife biologists may be trained and authorized to conduct chemical anesthesia under the remote guidance of a certified veterinarian. As either approach may be a possibility for this project, the associated costs can be variable. To ensure the collaring process is efficient and effective, it is recommended that a team of three biologists assist the veterinarian during the capture and collaring operations. Their role would include restraining and carrying pigs, as well as handling other logistical tasks, such as taking measurements and monitoring vitals, to ensure that the collaring proceeds quickly and smoothly. This collaring effort should be scheduled during a time of year when pig capture success is typically high within the areas where collars are to be deployed. This timing will maximize the likelihood of capturing suitable pigs for collaring, thereby increasing the efficiency of collar deployment. To further enhance the efficiency and cost-effectiveness of the collaring effort, the following preparatory steps should be taken:

- **Trap Placement and Pre-Baiting:** A sufficient number of traps should be strategically placed in areas where pigs are known to frequent. These traps should be pre-baited in advance of the collaring operation to condition pigs to enter the traps.

- **Camera Monitoring:** Cameras should be placed on bait piles to monitor pig activity and confirm the reliable presence of suitable pigs for collaring. Camera monitoring will help ensure that the collaring team targets areas with high pig activity, reducing the time and resources needed to collar the animals.

The amount and type of capture and restraint equipment necessary to support collaring will vary based on who is hired to provide collaring services and additional logistics that are unknown at this time. Additional costs may be necessary for collaring equipment and drugs, or a mobile veterinarian may be available, for a slightly higher labor rate, that will include all necessary capture equipment.

Collars should be monitored at least weekly, and data downloaded and coarsely reviewed at least monthly, to ensure that collars are functioning properly and that study subjects are still alive. If collars fail or if mortality of study subjects is detected, those incidents should be investigated to determine what happened, to recover collars if applicable, and to inform improved collar study design or deployment during subsequent efforts. If collared pigs are recaptured during pig removal efforts, and the pigs and collars appear to be in good shape, while the collar is still transmitting, they should be rereleased to allow for continued data collection. Collaring and recollaring of pigs should be continued and expanded upon beyond the initial effort, as feasible. By placing collars on new subjects as needed to always maintain a minimum of five to ten collared pigs within the Network. Collars removed from pigs that die or are euthanized as a part of pig control efforts, may be fitted on new pigs immediately, if still functional.

Given the complexity and the need for site-specific detailed planning, and an undetermined timeframe for the work, more time and information (than currently available for this plan) are required to design a comprehensive collaring study and the associated trapping efforts. This is important to ensure clarity in budgeting and avoid underestimating the resources needed for the overall study. As a result, there are no costs outlined in this Plan for the expenses related to trapping or collaring pigs for this effort. A separate, detailed plan and budget will need to be developed to ensure that the collaring study is adequately supported and that all aspects of the project are thoroughly considered and effectively implemented.

Targeted Whole Sounder Trapping to Improve Population Control

To complement current trapping efforts for this program, and to support more effective pig population reduction, an additional, modified trapping effort is recommended. At a minimum of twice per year, a focused trapping effort should be conducted to target and remove whole sounders from within high-priority locations, ahead of breeding periods to affect the greatest population growth control within those areas. Camera monitoring arrays should be used to identify specific sounders to be targeted, with pre-baiting and trapping efforts commencing shortly afterwards. Trapping should be conducted by a team, to increase efficiency of removal of large numbers of pigs within the identified time period. Trapping should include the use of larger traps, capable of capturing whole sounders. These efforts should be conducted in areas within or adjacent to camera arrays, including in areas away from roads where year-round trapping is not conducted. Individuals, identified on camera, that are not captured should be targeted through other methods, such as the use of firearms, during daytime and/or nighttime hours. Short-term monitoring would follow removal efforts to confirm the success of WSR, with additional removal efforts employed, as necessary and/or feasible.

Long-term Program Maintenance

An integrated pig management approach will be used to guide the Network pig management program, wherein the most effective, selective, and environmentally desirable method or combination of methods will be tailored to site-specific field conditions. Variables encountered in the field, such as location, topography, land uses, vegetation type, and number of pigs, will be used to decide which management methods are most suitable for implementation.

Maintenance of an effective pig management program within the Network should comprise a long-term commitment and collaboration from all partner organizations. Pigs are expected to move between partner organization lands, private landowners, and properties owned by other entities (e.g., cities). The pig population is likely interconnected, where pig movements are not prevented by hard barriers (i.e., dense urban areas or large highways). Therefore, pigs should be managed collectively, and congruently, while working towards shared goals.

The following recommendations are provided to support long-term maintenance of an effective pig management program within the Network:

- Work continuously to improve regional collaboration and coordination regarding pig management. Provide and discuss recommendations for collaborating with other land management agencies and private entities on region-wide pig population control.
- Each partner organization should make a commitment to pursue funding to support annual costs of this adaptive program until pigs are eradicated and/or fencing is installed to effectively prevent pigs from entering Network properties. Loss of funding during a given year could undermine previous efforts, possibly allowing the pig population to rebound.
- Increase the number of pig management personnel and/or teams providing pig removal and other management for the Network. Effective pig population control can be extremely difficult to achieve, due to extremely high fecundity rates, adaptability, and intelligence. This can be true for much smaller areas (<10,000 acres), so an adequate reduction in the pig population on Network lands is unlikely with the current level of effort.
- Adhere to and build upon the recommendations provided within the "Low-effort Population Monitoring" portion of this document. This should continue to adapt and improve efficiency of data collection to support effective population tracking and evaluation of management methods.

    > "Develop and implement data input systems, training materials, and public or park visitor engagement and evaluate at least annually. As new programs, materials, or resources become available to support this aspect of the program, ensure that materials remain current and relevant. A basic in-person or virtual training program or accessible video could be created for each data input system and relevant field employees required to take the training."

- Design and implement a camera monitoring strategy. Continue to maintain and improve that camera monitoring strategy as lessons are learned regarding how and where to best operate cameras to maximize effectiveness of monitoring and pig removal.

    > "For long-term population monitoring, camera trapping arrays should be designed, tested, implemented and employed at least once per year and operated for a minimum of ten days each. Camera array surveys should be scheduled ahead of suspected breeding periods for identifying, evaluating, and targeting the number, location, and composition of sounders before breeding, allowing for more focused removal efforts that can be better planned and executed. By operating cameras both before and after pig removal efforts, the effectiveness of pig removal efforts and effects on the pig population would be better measured. This proactive approach will help reduce

population growth and manage pig populations (e.g., WSR) more effectively over time."

- A customized camera or in-person surveillance (e.g., night optics and/or drone surveys) scheme should be developed for priority areas. The surveillance scheme would provide early detection of pig immigration into or near priority areas and support WSR.
- A rapid response plan should be developed to allow expedited management actions to neutralize newly identified threats in high-priority sensitive areas.
- Create standardized figures and summary tables to review pig data within each Network partner properties and for the Network as whole. Combine data for all Network entities regularly and discuss results during at least an annual Network meeting; however, more frequent reviews and discussions may be necessary during the development stages of the program (i.e., quarterly). Long-term trends should be compared to long-term goals and methods applied and results evaluated. Only the most efficient and effective methods for reaching long-term goals should be continued.
- Develop both short-term and long-term plans to exclude pigs from areas by installing and maintaining pig-proof fencing.
- To ensure that the most efficient methods, equipment, and applications are being used to maximize efficacy within the Network program, the latest peer reviewed literature stemming from pig programs should be evaluated for potential integration into the pig management program. Additionally, efforts should be made to attend national or international pig conferences to learn more about innovative techniques being used effectively within other programs. Such techniques should be shared and discussed between Network partners for consideration of testing and/or implementation.
- As a part of improved data collection protocols for pig presence, damage, and control efforts, all pig management efforts should be recorded digitally and georeferenced, then compared to pig presence data reported through various sources, to establish measures of success and evaluate effectiveness of pig control efforts. All efforts, and their success or lack of, should be evaluated quarterly during the initial stages of program development and at least annually after the program is more developed and running smoothly.

SECTION 11: PHASED APPROACH TO PROGRAM DEVELOPMENT

The plan will be implemented in the following phases:

Phase I: Initial Program Development

1. Identify broad pig management program goals, within each partner organization, and for the Network as whole.
2. Break those goals down and identify a timeline and projected budget for each.
3. Identify and establish a regular meeting schedule to discuss pig management efforts with all Network organizations. Develop a structured program agenda that will occur during those meetings.
4. Identify funding sources that are likely to support program needs and timelines for acquiring each funding source.
5. Develop databases and associated data input systems to standardize collection of pig related data across all entities and facilitate easy combination for evaluation. Develop data collection protocols to be followed by all Network staff and pig control contractors when collecting data and identify means of providing access to digital data collection apps and training to all entities that may collect pig related data.
6. Design camera monitoring arrays and fixed-point pig detection stations within or near high priority areas.
7. Develop a supplemental trapping scheme for all or selected camera arrays.
8. Design a pig collaring study.
9. Explore feasibility of fencing within Network properties. If feasible, develop a plan for implementing fencing at selected areas.
10. Identify measures of success for each management technique to be implemented.
11. Begin regular program evaluation using performance metrics

Phase II: Program Maintenance and Building

1. Implement data collection protocols.
2. Implement camera population assessment surveys and pig detection stations, to help to estimate the pig population present with LU's, Network properties, and priority areas.
3. Implement supplemental targeted WSR trapping.
4. Deploy collars.
5. Continue regular program evaluation using performance metrics.

Phase III: Program Evaluation and Adaptative Management

1. Analyze data collected during Phase II.
2. Evaluate methodology and results of the program to determine potential successes or failures and identify modifications needed for enhancing the effectiveness and efficiency of the program to best achieve goals.
3. Expand use and coverage of techniques that are proven successful and reevaluate, adapt,

and/or remove methods that are ineffective.

4. Continue to stay informed of and explore the use of innovative new techniques that could potentially be incorporated into the pig management program.

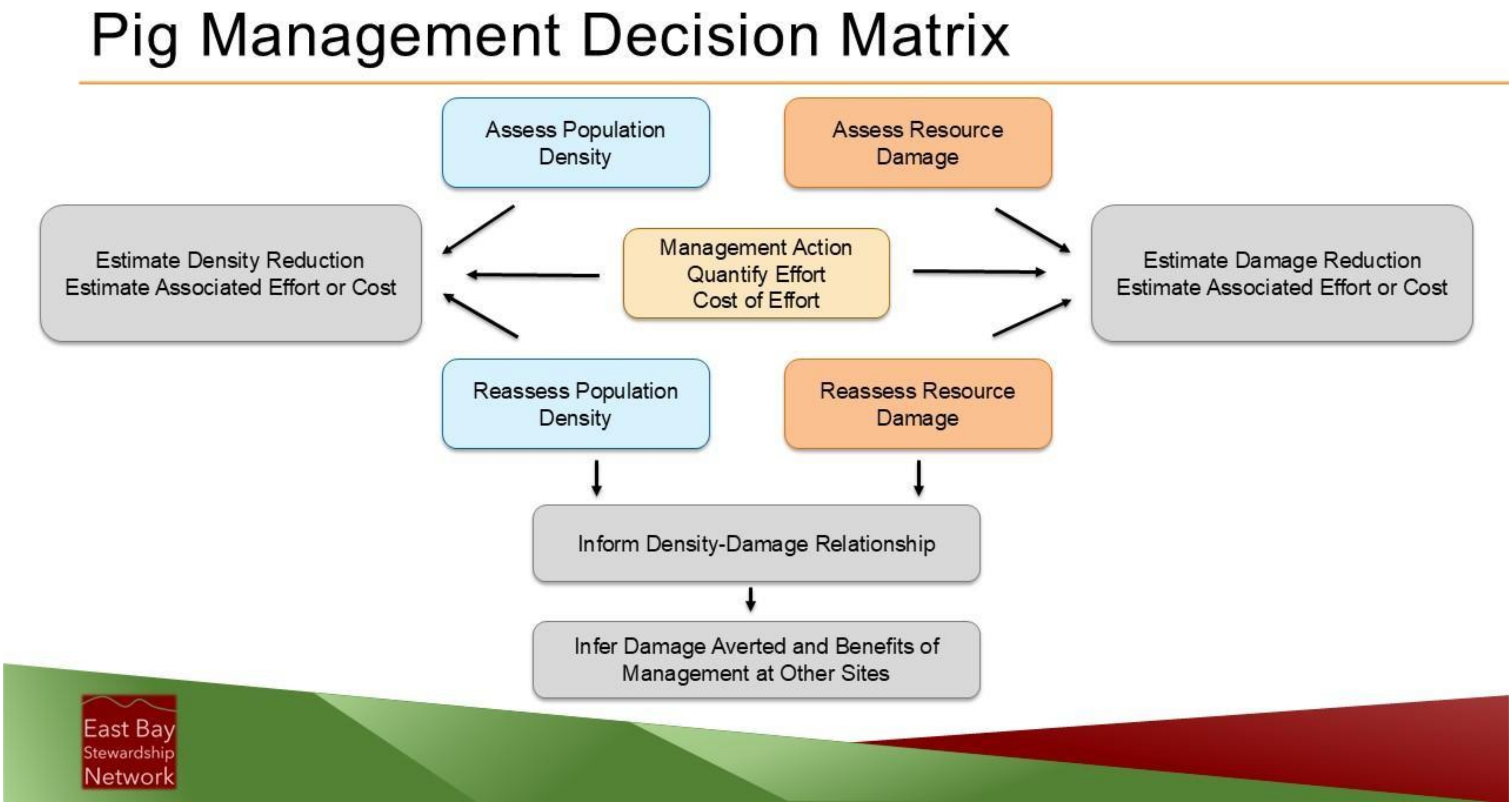

Figure 45. Example decision matrix to support pig management within the Network. Figure taken from VerCauteren *et al.* 2020.

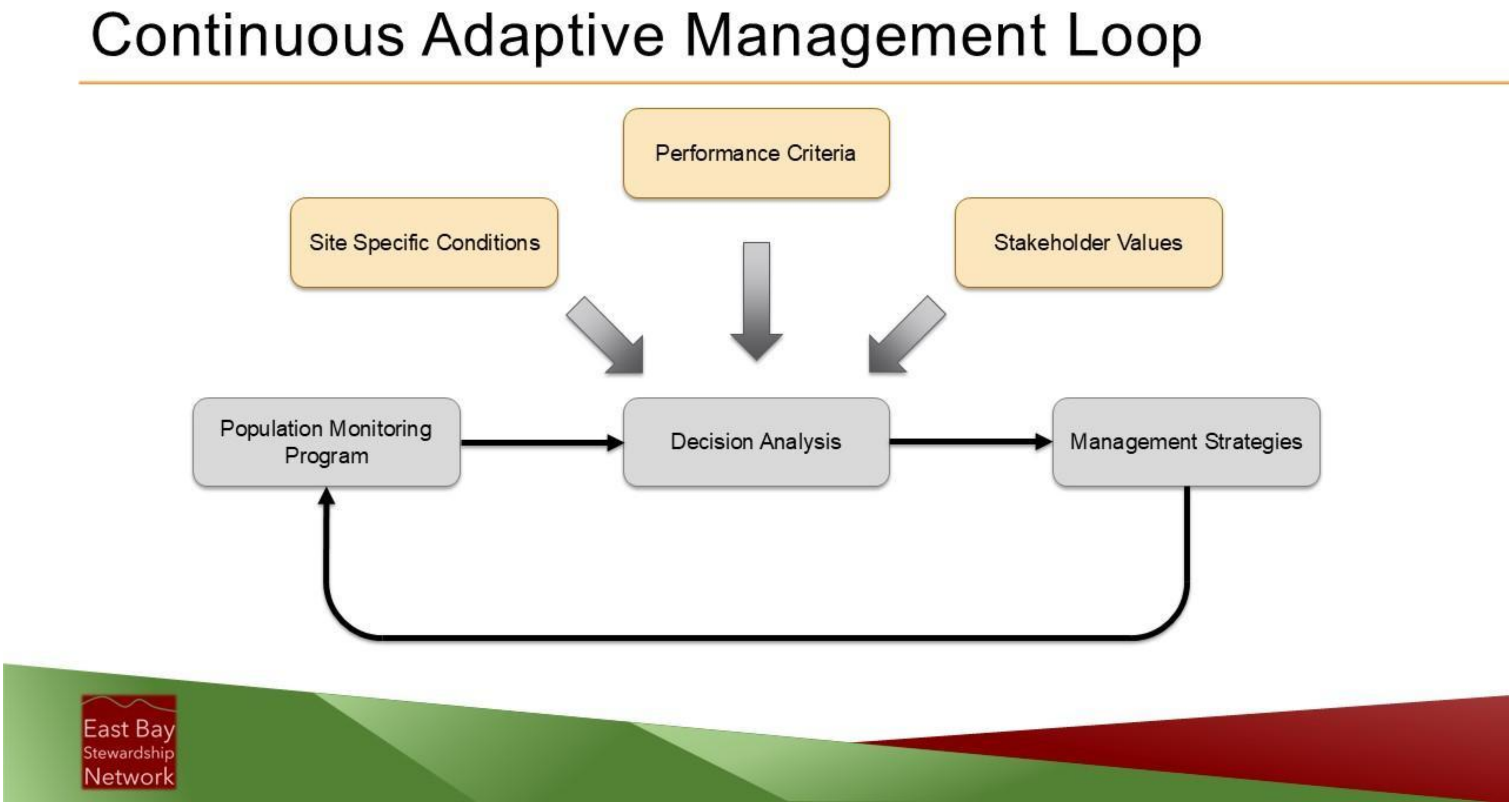

Figure 46. Example decision matrix to support pig management within the Network. Figure taken from Brondum *et al.* 2017.

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