Appendix B Covered Species Profiles

B.1 Morro Shoulderband Snail (*Helminthoglypta walkeriana*)

B.1.1 Listing and Conservation Status

The Morro shoulderband snail (*Helminthoglypta walkeriana*: Helminthoglyptidae) is a federally listed threatened species (USFWS 1994, USFWS 2022). The U.S. Fish and Wildlife Service (USFWS) completed a recovery plan for the endangered snail and four plants from western San Luis Obispo County (USFWS 1998a) and designated critical habitat for Morro shoulderband snail (USFWS 2001). The USFWS conducted a five-year review for this species in 2006, providing additional information about its ecology and conservation status (USFWS 2006).

B.1.1.1 Recovery Plan

The recovery plan for Morro shoulderband snail, which also addresses Morro manzanita and Indian Knob mountainbalm and two other plant species that are not present in the LOHCP Area, identifies four conservation planning areas in and around Los Osos that support other listed and sensitive species and where recovery potential is high. Specific criteria used to designate the planning areas where conservation activities should be focused included:

1. The distributions of the Morro manzanita, Morro shoulderband snail, and Indian Knob mountainbalm overlap or are contiguous with one another, with historic or occupied habitat for the Morro Bay kangaroo rat, or with the distributions of other sensitive species; and,
2. Natural habitats are relatively large and unfragmented by development; or,
3. Natural habitats are in public ownership or are adjacent to areas that are already secured and are to be managed for their biological diversity.

The recovery plan set as a down-listing criterion protection of relatively unfragmented habitat blocks in each of the four conservation planning areas that can support populations that are large enough to minimize extinction risk in the short term (i.e., for the next 50 years). The recovery plan also provides guidance on management of these areas to recover the Morro shoulderband snail, which requires intact habitat that is relatively unfragmented by urban development, and is secure from threats of exotic snail predation, pesticides, recreational use, and invasion of exotic plants. Special management needs include controlling exotic pest plants to maintain intact native habitat, restoring and maintaining connectivity among isolated populations to preserve genetic diversity, controlling pesticides in snail areas, controlling exotic predatory snails, and restoring native plant communities.

In the first in-depth review of the species' status since the recovery plan was developed, the USFWS (2006) concluded in its five-year review that Morro shoulderband snail populations are stable to increasing, and that threats due to habitat loss and degradation have been reduced considerably. The USFWS also stated its intention to work to expand habitat maintenance activities in other areas essential for the species using habitat conservation plans and other regulatory mechanisms as applicable (USFWS 2006). A five-year review recommended that the species be down listed to 'threatened' (USFWS 2006). ON February 3, 2022 Morro shoulderband snail was downlisted from 'endangered' to 'threatened' (USFWS 2022).

B.1.1.2 Critical Habitat

The USFWS designated critical habitat for MSS throughout the species' existing range. Within this area, the primary constituent habitat elements are: sand or sandy soils needed for reproduction; a slope not greater than 10 percent to facilitate movement of individuals; and the presence of native coastal sage scrub vegetation. This vegetation is typically, but not exclusively, represented by mock heather (*Ericameria ericoides*), seaside buckwheat (*Eriogonum parvifolium*), eriastrum (*Eriastrum densifolium*), dune lupine (*Lupinus chamissonis*) and dudleya (*Dudleya sp*.); and in more inland locations by California sagebrush (*Artemesia californica*), coyote brush (*Baccharis pilularis*) and black sage (*Salvia mellifera*) (USFWS 2001).

Critical habitat mapped in three units total approximately 2,576[24] acres (Figure 4-4). The units correspond to the areas delimited in the recovery plan, with except that the Morro Spit and West Pecho units were merged for purposes of critical habitat (Figure 4-3).

Unit 1: Morro Spit and West Pecho: This unit consists of 1,831 acres of land that is largely (90.4%) protected and managed by Montaña de Oro State Park (Dunes Natural Preserve) and the City of Morro Bay (north end of spit), including the length of the spit and the foredune areas extending south toward Hazard Canyon, and private lands further inland. It features several significant viable populations of MSS and is deemed essential to maintaining genetic diversity of the species. The LOHCP Area includes 376 acres (20.5%) of this unit.

Unit 2: South Los Osos: Unit 2 features 331 acres on the lower slopes of the Irish Hills that supports central maritime chaparral and coastal sage scrub. Located almost entirely within the LOHCP Area (33, this area is considered essential to the conservation of the Morro shoulderband snail because, appropriate management maintain habitat allowing the core population to expand and threats to the species to be reduced (USFWS 2001). Of the 661 acres, 282 (85%) is protected within the Bayview Unit of the Morro Dunes Ecological Reserve and the County's Broderson Property.

Unit 3: Northeast Los Osos: This 414-acre unit, of which 274 acres (66%) is within the Plan Area, includes 256 acres (62%) that is protected in State and County-owned Elfin Forest Preserve and portions of Morro Bay State Park. It features 416 acres of undeveloped area between Los Osos Creek and Baywood Park, which supports coastal sage scrub, with scattered stands of central maritime chaparral and coast live oak woodland (*Quercus agrifolia*). Protection and recovery of this unit is essential to maintain the genetic variability of the species and the full range of ecological setting within which the snail is found. Habitat conditions are favorable for the expansion and persistence of the core population and, with the reduction of threats through appropriate management, this area could support a larger Morro shoulderband snail population and contribute to the recovery of the species (USFWS 2001).

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[24] This is the acreage in a geographic information system shapefile produced by the USFWS, which differs slightly from the 2,556 acres listed in the critical habitat designation (USFWS 2001).

B.1.2 Available Information

Morro shoulderband snail research has examined the species taxonomy and morphology (Pilsbry 1939, Miller 1985, Roth 1985, Walgren 2003a, Tupen and Roth 2005) b), geographic distribution (Walgren 2003a), and habitat specificity (Adams et al. 2000, Reeves et al. 2000). These and other studies have used observations to hypothesize about aspects of the animal's dispersal (Walgren 2003a), parasitism (Hill 1974, Walgren 2003a), and competition within introduced snails (Hill 1974, Walgren 2003a). Additional information about the distribution, abundance, and habitat of MSS has been developed through pre-project surveys and salvage conducted to construct and hook up homes and business to the Los Osos Wastewater Treatment Plant (SWCA 2012-2017).

B.1.3 Taxonomy

Also commonly known as the banded dune snail (USFWS 1998a), the Morro shoulderband snail (*Helminthoglypta walkeriana*) is a member of the Helminthoglypta family which is in the Class Gastropoda of the Phylum Mollusca. Species in the genus *Helminthoglypta* occur in a wide range of habitats west of the Sierra Nevada from Baja California to southwestern Oregon (Miller 1985) and have similar shell characteristics, which include the shoulderband—a revolving dark band on the shell (Walgren 2003a). Based on morphometric analysis of shell characteristics, Walgren (2003b) recommended that MSS populations be divided into two subspecies, which were as recognized at the time of MSS listing in 1944 as *H. w. walkeriana* and *H. w. morroensis*. Roth and Tupen (2004) argued for the separation of two distinct species: *H. walkeriana* and *H. morroensis*. The USFWS accepted the results of Roth and Tupen (2004) that elevated to the taxa to the species level (USFWS 2006).

B.1.4 Description

Morro shoulderband snail is a terrestrial snail with a slightly translucent shell featuring 5-6 whorls. Its shell is 18-29 mm in diameter and 14-25 mm tall (Roth 1985). The Morro shoulderband snail can be differentiated from the Big Sur shoulderband snail (*Helminthoglypta umbilicata*) as the MSS has incised spiral grooves and an occluded umbilicus—the cavity in the center of the base of the shell that is surrounded by the whorls. Rather than a distinct band, the exotic brown garden snail (*Helix asper*) has a marbled color pattern on its shell and a completely occluded umbilicus (Roth 1985, Walgren 2003a). In differentiating between subspecies of *H. walkeriana*, Walgren (2003b) defined *H. w. morroensis* by its profuse, coarse, papillations (bumps) and weak incised spiral grooves and *H. w. walkeriana* by its weak papillation and strong incised spiral grooves. He found that *H. w. walkeriana* was larger at time of sexual maturity than *H. w. morroensis*.

B.1.5 Distribution

The current known range of Morro shoulderband snail is approximately 7,700 acres (Roth and Tupen 2004). Most of the area is centered on Los Osos north of Hazard Canyon, west of Los Osos Creek, and south of Morro Bay; however, it also includes a narrow strip of coastal dunes north of Morro Bay in Morro Strand State Park (Roth and Tupen 2004, USFWS 2006).

B.1.6 Habitat

Within the Los Osos area, the Morro shoulderband is primarily found on the Baywood fine sands soils and the active dunes of the Morro Bay sand spit (Walgren 2003a). In a single location, MSS were observed on a “clay” soil in Los Osos Oaks Reserve approximately 200 m from the nearest mapped Baywood fine sands soil. Based on this description, the “clay” soil was likely the Conception loam, which has a higher proportion of smaller soil particles (clay and silt) than Baywood fine sands (USDA 1984). However, other locations supporting live snails were all located on Baywood fine sand soils (Walgren 2003a).

Due to a combination of factors which affect plant growth, including topography, soil conditions, disturbance history, and land use history, the Baywood fine sand soils support a diverse mosaic of plant assemblages varying from open dunes to dense woodlands. Originally, MSS was thought to be restricted to coastal dune and scrub communities which predominant in the Los Osos region (Roth 1985, USFWS 1998a, 2001). It was hypothesized that early and mid-successional coastal sage scrub communities would provide optimal MSS habitat by featuring greater density of immature shrubs which, unlike mature shrubs, have lower branches in contact with the soil (Roth 1985).

The California Department of Parks and Recreation commissioned two studies to characterize the distribution and habitat of MSS within coastal dune and coastal sage scrub of the Los Osos region (Adams et al. 2000, Reeves et al. 2000), and a third study examined the distribution of MSS with respect to eucalyptus (Walgren and Andreano 2012).

Adams et al. (2000) examined vegetation characteristics near Shark’s Inlet then sampled the abundance of MSS and characterized the vegetation in 101 plots randomly located in “representative vegetation” in the Montana de Oro and the Elfin Forest. The analyses based on biased sampling in which a greater number of plots were deliberately located within coastal sage scrub preclude determination of whether the MSS is preferentially found within the different community types described and mapped. The study did not examine potential correlations of snail distribution and abundance with individual plant species or other habitat characteristics. However, the researchers reported that, of the 44 MSS observed in the 101 sampled 20 m^2 circular quadrats, 26 were found in the litter under mock heather (*Ericameria ericoides*) and 14 were found under iceplant (*Carpobrotus* sp.) (Adams et al. 2000).

Reeves et al. (2000) sampled litter, vegetation, and MSS abundance in 3.14 m^2 quadrats located along transects deliberately located within known MSS populations at three sites: the Sand Spit and Sharks Inlet areas of Montaña de Oro State Park and the Elfin Forest. Their results indicated the following:

- MSS occurred in plots with 17% more litter cover by weight than habitat without;
- MSS occupied plots with 10% less open sand and therefore more plant cover;
- Species composition in plots with MSS differed from those without, though not single plant species were predictive of MSS occurrence;
- *Senecio blochmanii, Eriogonum parvifolium, Corethrogyne filaginifolia* var. *filaginifolia* and *Dudleya lanceolata* showed trends toward greater abundance in plots with MSS that those without MSS;
- *Corethrogyne filaginifolia* var. *californica* and *Artemesia californica* exhibited trends toward lower abundance in plots with MSS than those without MSS;

- MSS was more likely to be found in plots with greater percentage of vegetation in contact with the soil; and,
- Live MSS snails occurred with MSS shells in the 3.14 m^2 plots more likely than predicted by chance alone, suggesting that MSS may occupy the same small patches through time.

During a more recent distribution survey of the Los Osos Valley, Walgren (2003b) observed Morro shoulderband snails in a variety of plant associations that he classified as follows:

- coast live oak woodland;
- California annual grassland;
- dune lupine-goldenbush;
- introduced perennial grasslands (*Ammophila* sp. and *Ehrharta* sp.); and
- iceplants.

In a more recent study, Walgren and Andreano (2012) evaluated MSS distribution with respect to eucalyptus (*E. cephalocarpa*) in Montaña de Oro State Park and found just one MSS under the exotic tree canopy compared to 37 MSS in intact habitat away from the exotic trees. A lower number of MSS were similarly salvaged from eucalyptus litter than from coastal sage scrub and veldt grass areas in the Broderson site, as part of efforts to capture and relocate MSS at the Broderson site as part of the wastewater treatment plant (SWCA 2013). Though the mechanisms limiting MSS abundance under eucalyptus are unknown, it may reflect alterations in the availability of plant detritus, competition (including predation) by other snail species, and/or modifications to abiotic habitat conditions, including light, temperature, moisture, or soil chemistry (Walgren and Andreano 2012).

Though there is little information about the relative abundance of MSS within these communities, these observations suggest that the species occupies a wider range of plant communities within the Baywood fine sand soils than simply coastal dune and sage scrub. Importantly, the species has been found in association with a variety of anthropogenically disturbed habitat areas, including areas where coastal sage scrub has been converted to non-native grassland due to vegetation clearing and mowing, areas covered by veldt grass and iceplant, landscaping and ornamental plantings, woodpiles, and other habitats within developed areas and rights-of-way (SWCA 2013, 2014, 2015, 2016, and 2017). Indeed, frequent observation of MSS within a range of habitat conditions found within existing developed parcels areas as well as remaining vacant parcels suggest MSS has the potential to occur throughout the urban services line and Los Osos Wastewater Treatment Plant Area (Figure 2-2), as well as intact habitat on the perimeter of the Plan Area.

Based on his observations and the results of Adams et al. (2000) and Reeves et al. (2000), Walgren (2003a) suggests that snail presence may be primarily influenced by moisture retention and protection from solar radiation, which are in turn influenced by leaf litter density, vegetation density, and the extent to which the vegetation is in contact with the soil, and that the species of plant is less important in predicting soil presence than its habit or physiognomy. This finding is similar to that observed for the congener *H. arrosa*, which was deemed a habitat generalist as it inhabits a variety of coastal communities on Bodega Head, in Sonoma County, California (Van der Laan 1971).

B.1.7 Life History

Few studies have examined aspects of the ecology or life history of the Morro shoulderband snail. The following summary provides current known and hypothesized information; however, much more research is needed.

B.1.7.1 Longevity

No studies have examined the life cycle of MSS. Based on population biology research on the congeneric *Helminthoglypta arrosa* (Van der Laan 1971), Roth (1985) hypothesized that MSS may live six to ten years and reach sexual maturity at three years. Growth of MSS is determinant, and sexual maturity is reached shortly after maximum size is attained. When compared to adult MSS, immature shells are smaller, have fewer whorls, and lack an aperture lip (Roth 1985).

B.1.7.2 Activity and Behavior

Like all land snails, which are susceptible to desiccation, MSS activity is closely tied to moisture. They are primarily active during or soon after rainfall events during the wet season (November – March). During the dry season (May-October), their activity is tied to the occurrence of precipitation from dense coastal fog, which can be frequent especially during the early morning hours; however, they are occasionally observed during dry periods within the rainy season (Ballantyne 2016). During dry periods, MSS likely estivate within the litter layer or below ground covering vegetation to avoid desiccation (Roth 1985).

Morro shoulderband snails are most often observed underneath plant or litter cover. Hill (1974) noted that the five snails he located during searches of the lower limbs and litter of vegetation were attached to the undersides of limbs of mock heather (*Ericameria ericoides*). The five live MSS individuals observed by Roth (1985) were under a mat of *Carpobrotus* sp. (n=3) or under boards located in the habitat. Though the small number of observations and methods of searching in both studies do not enable definitive conclusions about microhabitat, these observations are consistent with the behavior of reducing exposure to radiant energy, wind, and predators. These observations are similar to those of the congener *H. arrosa*, which frequently attached to the trunks of bush lupine (*Lupinus arboreus*) in the coastal scrub of Bodega Bay, CA (Van der Laan 1971).

Roth (1985) did not locate MSS below the surface of the soil during excavations around the base of mock heather, and thus stated that it appears the species is not fossorial. He did not quantify the level of effort in the search, and it is not clear whether additional searches in different years, sites, and/or plant species might provide different results. During efforts to capture and relocate MSS as part of the Los Osos Wastewater Treatment Plan project construction, biologists observed MSS occurring in shallow divots in the soil, of no more than half of an inch (Belt 2016, Ballantyne 2016).

At Bodega Head in Sonoma County, a coastal area supporting coastal scrub vegetation, *H. aspersa* was typically active during reduce solar illumination, including under overcast skies and at night (Van der Laan 1971).

B.1.7.3 Reproduction

No studies have examined the reproductive ecology of Morro shoulderband snails. Based on a study of the congener *H. arrosa* in coastal Sonoma County (Van der Laan 1971) and the constraints on snail activity that result from the marked dry season in the Mediterranean climate of Los Osos, Roth (1985) hypothesized that copulation, oviposition, and growth of MSS occur primarily during the wet season (November – April).

The eggs of MSS may be susceptible to mortality caused by desiccation or heat. Roth (1985) observed desiccated 2 mm diameter eggs in mock heather (*Ericameria ericoides*) litter on the Morro Spit, which he attributed to Helminthoglypta spp., though could not distinguish between *H. walkeriana* and *H. umbilicata*. Because most eggs of *H. arrosa* were viable (Van der Laan 1971), Roth (1985) suggested that drought and/or heat may have caused mortality of the eggs he observed. Due to the abundance of scattered eggs relative to the low density of live MSS, Roth (1985) speculated that the eggs were a result of several years of oviposition.

B.1.7.4 Feeding

There have been no studies to determine the feeding ecology of the Morro shoulderband snail. Hill (1974) suggests that the rows of small file-like structures in the radula (mouth parts) of the MSS are consistent with that of herbivorous land snails and that MSS may feed on fungal mycelia in litter. However, no studies have been conducted to test these hypotheses (Walgren 2003a).

B.1.7.5 Competition

Within the Los Osos Valley, MSS co-occur with four other snail species: Big Sur shoulderband (*Helminthoglypta umbilicata*), Chorro shoulderband snail (*H. morroensis*), brown garden snail (*Helix aspersa*), cellar glass snail (*Oxychilius cellarius*), and California lancetooth (*Haplotrema minimum*; Walgren 2003a, Tenera 2006). Hill (1974) suggested that, because brown garden snails co-occur with MSS and because he observed each species on the same plant, brown garden snails compete with MSS.

Roth (1985) and Walgren (2003a) both point out that there is weak evidence to support the claim that brown garden snails compete with MSS. Roth (1985) observed that brown garden snails inhabit the interior portions of shrubs and MSS the litter near the canopy edge. Walgren (2003a) noted that the brown garden snail is primarily found in wetter microsites, including perennial wetlands, along estuaries and riparian edges, and near human structures, where MSS are also known to occur (SWCA 2013).

In the 101 sampled $20m^2$ circular quadrats located within coastal dune and sage scrub within Montaña de Oro State Park, Adams et al. (2000) found 46 Morro shoulderband snails in a total of 21 quadrats, 2 of which contained a total of 6 live brown garden snails, and 9 of which contained a total of 37 Big Sur shoulderband snails. The researchers note that the greatest number of MSS were observed in two quadrats that lacked Big Sur shoulderband and brown garden snails (n=10 and n=4). However, this observation could suggest different microhabitat affinities (Walgren 2003a) as well as interspecific competition.

Though more research is needed to evaluate the effects of competition on MSS, management should still prevent the invasion and spread of brown gardens snails, as well as other exotic animals, into MSS habitat.

B.1.7.6 Predation

Heagy (1980) speculated that deer mice (*Peromyscus maniculatus*), alligator lizards (*Elgaria coerulea*), and unidentified beetles may prey upon MSS as they do with other snail species. Roth suggested that a broken MSS shell was indicative of rodent kill (Roth 1985). The shells of MSS have been observed on the feeding perches of unidentified birds (Walgren 2004.).

In nearby Diablo Canyon, the Decollate snail (*Rumina decollata*), an introduced, predatory snail, has been observed. These snails are sold in nurseries in unregulated counties and states as a way to control garden snails. Introduction of this snail may present a threat to MSS (Walgren 2004). It is unknown whether these snails currently occur within the range of Morro shoulderband snail.

B.1.7.7 Parasitism

The presence of Sarcophagid fly puparia (pupa casings) within Morro shoulderband snail shells has lead researchers to hypothesize that MSS are parasitized by these flies (Hill 1974, Roth 1985). Walgren (2003a) points out that the presence of puparia cannot be used to infer parasitism as Sarcophagid flies commonly feed on dead flesh and may simply be saprophagous (i.e., carrion feeders). In their study, Adams et al. (2000) observed no evidence of parasitism in 121 live MSS and Big Sur shoulderband snails sampled. Based on his literature review, field observations, and discussions with entomologists, Walgren suggests that the pupae found in MSS shells are from consumption of already dead snails (Walgren 2003a).

Two studies have documented the frequency of occurrence of Sarcophagid fly puparia within MSS shells. Walgren (2003a) found that the frequency of puparia presence ranged from 1.9% to 32% among 7 sites sampled throughout the range of H. w. walkeriana and H. w. morroensis. At Montaña de Oro State park, Adams et al. (2000) found that 3.7% (4 of 109) of MSS shells had Sarcophagid fly puparia.

If the presence of puparia does indeed indicate parasitism-induced mortality, it is not clear how these rates of would influence MSS population dynamics and persistence. Moreover, though attempts to identify the species of fly found in MSS shells have been foiled by difficulty in rearing the larva in the lab, there is no current evidence that the species of fly observed in MSS shells is non-native or introduced (Walgren 2003a).

B.1.8 Population Abundance and Density

No studies have quantified the abundance of MSS. In 1985, Roth estimated the total abundance of MSS as “in the hundreds”, though added that additional field research would be required to accurately estimate abundance (Roth 1985). Adams et al. (2000) sampled density of MSS in 101, 20 m^2 circular quadrats located on transects deliberately placed in habitat known or hypothesized to support populations of MSS. They reported densities ranging from 0 – 10 snails/ 20 m^2 but did not report the mean or variance for the samples. Though Reeves et al. (2000) also counted the number of MSS found within sampled quadrats along transects, they did not report the density of individuals observed.

Walgren (2003a) examined MSS presence/absence and thus did not report population abundance, though thought that, based on the number of individuals observed during distribution sampling, the population is likely greater than the hundreds estimated by Roth (1985).

As part of efforts to minimize the impacts of installation of the Los Osos Wastewater Treatment Plant and associated connections (i.e., laterals), biologists have conducted pre-disturbance surveys to capture and relocate MSS from disturbance areas since 2012. These surveys have been conducted on the County's Broderson and Midtown properties, where the wastewater treatment infrastructure was installed, and on hundreds of residential and commercial parcels, as well as adjacent County rights-of-where, where landowners are connecting buildings to the collection system. Since 2012, 2,121 MSS have been encountered during the surveys (SWCA 2016 and 2017). The survey reports do not indicate the total number of parcels or area surveyed, nor do they report negative findings, such that it is not possible to use these data to assess MSS frequency or density. Nonetheless, these surveys have indicated that MSS can be very abundant in the Plan Area, both in intact habitat as well as degraded habitat associated with existing development. For example, 404 MSS were captured at the County's 12.2-acre Midtown Property, while 245 were captured in a 0.14-acre parcel near San Luis Avenue and 6th Street (SWCA 2016).

B.1.9 Dispersal and Colonization

No studies have examined dispersal of MSS. Active dispersal of MSS would likely involve slow, short distance migration during periods of favorable conditions. Over time, perhaps several generations, the species could actively disperse larger distances, provided populations persist and favorable conditions are maintained.

As with other land snails, MSS active dispersal may be limited by natural and anthropogenic barriers. Natural barriers, such as bodies of water or inappropriate vegetation types (e.g., dense riparian vegetation or woodlands), may inhibit dispersal, either by preventing snail locomotion or by lacking the appropriate stimulants, such as food odors, to attract snails (New 1995). Human-created barriers such as structures, landscaping, wide trails, and roads can similarly inhibit snail movement. Roads may present particular barriers as they can cause desiccation if the snails cannot create sufficient mucus to traverse the dry surfaces.

Morro shoulderband snails might be able to disperse across barriers and over larger distances through passive migration. Various mammals, birds, and insects may vector the species, as could wind or rafting on floating objects. Human activity might also result in longer distance dispersal of MSS.
Walgren (2003a) suggests that MSS have colonized areas that were previously unoccupied. He observed live or recently dead MSS in three locations that had either been highly disturbed or created in the recent past (an artificial peninsula and an artificial dune created by deposition of dredged material and a former mine). Though they were not known to be deliberately introduced, it is not clear whether MSS naturally dispersed or if their colonization resulted from anthropogenic factors (Walgren 2003a).

B.1.10 Threats

Due to its limited geographic range (Los Osos Region) and narrow habitat specificity (Baywood fine sand soils and stabilized dunes), the Morro shoulderband snail is naturally rare. Though the original acreage of habitat occupied by the species is unknown, loss of habitat due to conversion for development and agriculture has no doubt reduced the distribution and abundance of MSS. Fragmented habitat may support smaller populations of MSS that would be more vulnerable to extirpation due to environmental stochasticity, such as fire, drought, or disease, reductions in population growth due to insufficient population size (Allee effects), and reduced fitness due to inbreeding depression. Frequent observations of MSS in areas of anthropogenically modified habitat, including landscaped areas (SWCA 2013), suggest populations may be able to persist in such areas.

Little is known about the factors that influence the distribution, abundance, and population persistence of Morro shoulderband snails, making it difficult to understand the threats to the populations within protected habitat. Previous reports have identified parasitism by Sacrophagid flies and competition from brown garden snails (*Helix asper*) as potential threats to MSS populations (Hill 1974, USFWS 1994, 2001); however, the five-year review for MSS concluded that there is no evidence to substantiate these threats (USFWS 2006).

Three additional factors that may threaten the persistence of MSS even within protected habitat: wildfire, unnatural succession due to fire exclusion, disturbance due to recreation, and the invasion and spread of exotic species.

B.1.10.1 Fire

A large wildfire could potentially threaten persistence of Morro shoulderband snail populations. Snails cannot evade fire, and unless the fire is cool or very patchy, it will likely kill all snails. Arson within Morro Strand State Beach killed all snails within the approximately three-acre area burned (M. Walgren, pers comm. 2004). State Parks ecologists have established permanent plots to monitor potential snail recolonization from adjacent, intact habitat; however, no data are yet available (Walgren 2003a).

Prescription fires designed to simulate the natural fire regime of the Baywood fine sand communities, increase native biodiversity, and facilitate populations of fire-adapted species including Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*), Morro manzanita (*Arctostaphylos morroensis*), and Indian Knob mountainbalm (*Eriodictyon altissimum)* could directly negatively impact populations of Morro shoulderband snail. Roth (1985) observed two recently dead MSS shells and no live snails after a 19-acre prescription fire in coastal sage scrub designed to enhance Morro Bay kangaroo rat habitat. Fire management should incorporate avoidance and minimizations measures designed to reduce the potential for such direct negative impacts and maximize the potential for fires to facilitate long term persistence of MSS populations, including removing snails prior to conducting burns and using small, narrow, rectangular burns that can enhance the likelihood of snail recolonization (Roth 1985, Simmons et al. 1995).

B.1.10.2 Fire Exclusion

Roth (1985) has hypothesized that MSS population growth is maximized in early to mid-successional coastal sage scrub habitat, where younger shrubs provide softer tissues for food and foliage that is contiguous with the ground litter layer, for shelter. Unnatural succession of the coastal dune and sage scrub plant communities due to widespread fire exclusion could reduce the areal extent of such early and mid-successional assemblages. The extent to which fire threatens MSS populations is unclear, however, because the species' specific habitat requirements are uncertain. Moreover, though fire is a natural component of the Baywood fine sand communities, aspects of the natural fire regime and the successional relationships between the plant assemblages are unknown. More research is needed to understand the role of fire in maintaining habitat conditions required for MSS.

B.1.10.3 Recreation

Recreation within the Baywood fine sand communities causes disturbance. It removes established plant cover, including litter, and depending on the intensity and frequency, causes erosion and prevents plant re-establishment. Because plants and their litter create cover and shade and retain moisture required by MSS, recreation that removes plant and litter cover degrades or removes habitat for MSS. Recreation can also directly kill MSS, as their size and low vagility limits their ability to move away approaching humans, horses, and bicycles. Dogs allowed to wander unrestrained through the habitat may eat, harass, or otherwise impact MSS. Equestrians and humans could also trample MSS.

B.1.10.4 Exotic Animals

Exotic animals including rats (*Rattus rattus* and *R. norvegicus*) and feral cats (*Felis domesticus*) may prey upon MSS and could reduce their populations. This potential has increased the proximity of MSS habitat to development, with which these species are associated. Introduced predatory snails such as *Oxycheilus* sp. and the Decollate snail (*Rumina decollata*), which was recently identified in Diablo Canyon, could similarly negatively impact MSS populations (Roth, 1985, Walgren 2004); however, there is currently no direct evidence that exotic animals impact MSS populations (USFWS 2006).

B.1.10.5 Exotic Plants

The invasion and spread of exotic plant species can potentially threaten the persistence of MSS populations by degrading habitat and thus reducing or eliminating MSS populations. Many exotic plants are presently found within remaining intact habitat in the Los Osos region. These species vary greatly in their distribution, abundance, and aspects of their ecology that influence their potential impacts to MSS, which also depend on aspects of MSS ecology.

In general, exotic plants might indirectly threaten MSS populations by a variety of mechanisms. First, invasive, exotic trees can transform the native shrublands into woodlands, rendering habitat conditions unsuitable for MSS. In a recent study, MSS was not observed within stands of eucalyptus (*Eucalyptus* sp.) (Adams et al. 2000) and MSS has not been described as occurring in eucalyptus forests in any other studies (Walgren 2004). These trees have invaded native vegetation from initial plantations in Montaña de Oro State Park and Los Osos. They produce abundant shade and litter and competitively exclude native shrubs and herbs, thus limiting the distribution of MSS. Other exotic trees within the region including Monterey pine (*Pinus radiata*) and Monterey cypress (*Callitropsis macrocarpa*) might similarly restrict the distribution of MSS.

Herbaceous exotic plant species including iceplants and grasses can outcompete and, in some cases, competitively exclude native plant species on which MSS might rely for food or shelter. The threatened snail has been found in a wide variety of plant assemblages on the Baywood fine sands, including those dominated by invasive exotic species including iceplant (*Carpobrotus* spp.), veldt grass (*Ehrharta calycina*), and annual grasses (*Avena* spp., *Bromus diandrus*, and *B. rubens* ssp. *madritensis*) (Walgren 2003a), as well as fennel (*Foeniculum vulgare*), and ornamental/landscape plants (SWCA 2013). Though these exotic plants may not restrict the distribution of MSS, areas infested by these exotic plants may support smaller populations of MSS, though this has not yet been examined.

Finally, exotic plants can enhance the flammability of the vegetation and thus increase the risk of wildfire, thus indirectly threatening MSS populations. Eucalyptus is highly flammable while the annual and perennial grasses that have invaded coastal sage scrub create dry, fine fuels in the summer that are highly flammable. MSS populations are likely to be completely eliminated by fire, as discussed above.

B.2 Morro Manzanita (*Arctostaphylos morroensis*)

B.2.1 Conservation Status

Morro manzanita (*Arctostaphylos morroensis* Wiesl & B. Shreiber Ericaceae), is a federally listed threatened species (USFWS 1994) and is ranked as most threatened and endangered according to the California Rare Plant Ranking (List 1B.1; CNPS 2016).

B.2.2 Available Information

A number of studies have examined many aspects of Morro manzanita biology, including: distribution and morphological variation (Mullany 1990), seed ecology and reproductive biology (Tyler and Odion 1996, Tyler et al. 1998, Tyler et al. 2000), and seed bank response to prescribed burning (Tyler et al. 2000, Odion and Tyler 2002). Research conducted on other species of *Arctostaphylos* in California, particularly those occurring in central maritime chaparral, provides additional information to help conserve and manage the endangered shrub. The USFWS conducted a five-year review for this species in 2008, providing additional information about its ecology and conservation status (USFWS 2008).

B.2.1 Distribution

Morro manzanita is endemic to the Los Osos region in coastal San Luis Obispo County where it occurs primarily on Baywood fine sands soils. Based on the likely historic distribution of these soils, Morro manzanita may have covered between 2,000 and 2,700 acres (McGuire and Morey 1992). Much of the Morro manzanita habitat has been converted for development, especially in the center of its historic range which is now occupied by the community of Los Osos. Currently, the range of *A. morroensis* is estimated to be approximately 840-890 acres, with the total number of individuals ranging between 86,000 and 153,000 (Crawford, Multari and Clark 2005).

B.2.2 Biology

B.2.2.1 Morphology

Morro manzanita is an evergreen tree-like shrub that grows to be 1.5-4.0 m tall. This non-burl forming manzanita has deep red stems with gray, shredding bark. The 2.5- to 4-cm long leaves are oblong to ovate to elliptic. Attached to the stems by 2- to 6-mm long petioles, Morro manzanita leaves nearly overlap along the stem, resulting in a whorled appearance despite their alternate arrangement (Hickman 1993). The upper surface of the leaves is dark green and smooth but can have a gray appearance due to a white or bluish film. The lower leaf surface is gray, owing to dense white hairs (Hickman 1993). Morro manzanita has white to pinkish urn shaped flowers that are 5- to 9-mm long and occur in dense racemes at the end of branches. The 8-13 mm diameter fruits are red to orange brown and contain 8 - 10 seeds each (Hickman 1993, USFWS 1994).

Morro manzanita can be differentiated from the co-occurring La Cruz manzanita (*Arctostaphylos cruzensis*) by the endangered shrub's shaggy grey bark, leaf base shape, and short woolly hairs on its lower leaf surface (USFWS 1994).

B.2.2.2 Phenology

Morro manzanita flowers in the mid-winter through early spring (January-May) and develops fruit between early spring (March) and early summer (Tyler et al. 2000). A 1999 study showed that fruits begin to fall from the plant as early as May, with the majority falling between August and early October (Tyler et al. 2000).

As with other shrubs in California's Mediterranean climate, Morro manzanita seeds likely germinate with the onset of the rains between October and December. In a study examining post-fire seedling establishment, maximum seedling abundance was observed in March, though no observations were made prior, making it difficult to say how early the seedlings established.

B.2.2.3 Life History

The age or size of shrubs at the onset of reproduction is currently unknown. Observations of small plants (<50 cm tall) with fruits on the old Broderson Road at the Bayview Unit of the Morro Dunes Ecological Reserve suggest that plants become reproductive within 5-8 years of establishment (J. McGraw, pers obs.)

Morro manzanita adults may be relatively long-lived. Analysis of historical aerial photographs combined with dendrochronology (annual ring counting of shrub stems) suggested that the oldest stands of Morro manzanita were 62 years old (in 2011); however, these analyses were constrained by the fact that earliest aerial photographs of the region were from 1949 (Tyler and Odion 1996). Tyler et al. (1998) observed recent mortality in the Elfin Forest stand, which was hypothesized to be the oldest stand of Morro manzanita (Tyler and Odion 1996). However, it is not known whether this mortality was the result of senescence or other site-specific conditions (e.g., soil pathogens).

B.2.3 Ecology

B.2.3.1 Habitat Preference

Though small portions are located on Santa Lucia shaly clay loam, Morro manzanita primarily occurs on the Baywood fine sand soils (Tyler et al. 2000). Formed from Pleistocene aeolian sand dunes, these soils are very deep and somewhat excessively drained. Due to its relatively coarse nature, the Baywood fine sand soils have low water holding capacity and, relative to loam and clay soils, low nutrient availability (H).

Of the three slope categories in the Baywood fine sand series (2-9% slope, 9-15% slope, and 15-30% slope), Morro manzanita cover is greater on the 9-15% and 15-30% slopes (Tyler and Odion 1996). This pattern may reflect the species' requirement for older, more developed soils that may feature a clay lens, which increases water holding capacity and thus is more conducive to the growth of large statured plants including Morro manzanita (JSA 1997). It could also reflect the disproportionately high rate of habitat conversion on areas of gentle slopes, which have been more recently cleared for agriculture than the steeper slopes (Tyler and Odion 1996). Determining whether Morro manzanita can persist on gentle slopes and whether it did prior to human alterations in the region is important for restoration and management.

B.2.3.2 Reproduction

Morro manzanita flowers are perfect; they contain both stamens and a pistil. These flowers are not self-fertilized, however, and instead require pollination to produce viable seed (Tyler et al. 1998, Tyler et al. 2000). It is not known whether plants are self-compatible; that is, whether viable seed can be produced from pollen from the same plant.

B.2.3.3 Pollination Biology

Pollinator studies conducted in 1998 and 1999 revealed that the most abundant pollinators of Morro manzanita were bumblebees (*Bombus vosnesenksii*). Addition pollinators include an Anthophorid bee (*Anthophora urbana*), several bee flies (*Bombylius* sp.) and Syrphid flies. In both years, the researchers noted the surprising low abundance of pollinator activity, even on warm, sunny days (Tyler et al. 1998, Tyler et al. 2000).

There is no record of Morro manzanita nectar robbery, in which animals obtain nectar from without pollinating the flower, typically by accessing nectaries through the corolla wall, rather than its aperture. Nectar robbery was observed to reduce seed production in the endangered silverleaf manzanita (*Arctostaphylos silvicola*), endemic to northern maritime chaparral in Santa Cruz County (Jacobson 1994).

B.2.3.4 Fruit Set

In 1998, an average of only 10% of Morro manzanita flowers produced fruits (Tyler et al. 1998). This rate is expected to vary from year to year depending on pollinator abundance, which can be influenced by spring weather, and flower production, which can be influenced by rainfall in the previous year when buds are produced (Keeley 1977).

B.2.3.5 Seed Biology

Morro manzanita is an obligate seeding species (Hickman 1993). Unlike many manzanita species (e.g., *Arctostaphylos tomentosa*), it does not have an underground burl from which it can regenerate following moderate to high intensity fires that consume aboveground biomass. Instead, population persistence requires successful germination of seeds.

Extensive research has been conducted to determine the factors which might influence the regeneration of Morro manzanita from seed following disturbance (Tyler and Odion 1996, Tyler 1996, Tyler et al. 1998, Tyler et al. 2000).

B.2.3.6 Seed Production

From limited available data, it is estimated that Morro manzanita produces 8-10 seeds per fruit (USFWS 1994).

B.2.3.7 Seed Predation

A 1998 study examining Morro manzanita fruit predation found that an average of 60% of fruits were removed from trays located under and away from Morro manzanita shrubs over a 46-day period (Tyler et al. 1998). Rodents, including woodrats (*Neotoma lepida*) and brush rabbits (*Sylvilagus bachmani*), were hypothesized to be responsible for removing fruits as their nests and scat, respectively, were observed near the experimental trays in which the fruits were placed. Because the fruits were presumed to be removed by small mammals, which eat seeds within the fruits (Keeley and Hays 1976), the authors concluded that fruit predation results in seed predation and thus dramatically reduces the amount of available seed (Tyler et al. 1998).

B.2.3.8 Seed Dispersal

Birds and large mammals including by coyote (*Canis latrans*) and mule deer (*Odocoileus hemionus*) may eat Morro manzanita fruits from the stems and perhaps disperse viable seed as observed for other species of manzanita (Keeley and Hays 1976). However, the majority of Morro manzanita seeds likely fall to the soil below. These may be secondarily dispersed by birds and mammals. Seeds not killed during digestion can be dispersed by these animals. However, a study in another California chaparral system found that the majority of *Arctostaphylos* seeds remained within the canopy radius (Keeley 1977). Tyler and Odion (1996) found that that soil cores extracted from 1.5 m away from the canopy edge had an average of 90% fewer seeds than cores taken below the Morro manzanita canopy, suggesting secondary dispersal is likely limited.

B.2.3.9 Seed Viability

Studies have found that Morro manzanita seed obtained from the litter and soil has low viability (Tyler and Odion 1996, Tyler et al. 1998, Tyler et al. 2000). In 1996, mean seed viability across four sites was 4.8%, with the Elfin Forest sites having only 1.7% viable seed. In both 1996 and 1998, 45% of seeds examined lacked an embryo (Tyler and Odion 1996, Tyler et al. 1998). Such low fertility could indicate inbreeding problems associated with small populations (Tyler and Odion 1996).

Viability was slightly, but significantly lower in the litter (3.6%) compared to the soil (5.8%) (Tyler et al. 2000). Seed viability varied among sampled shrubs and ranged from less than 1% to 11% (Tyler et al. 2000). Viability was not lower in the soil at a depth of 5-10 cm, compared the top 5 cm of soil (Tyler and Odion 1996). Viability of seed collected under and dead live shrubs also did not significantly differ (Tyler et al. 1998).

B.2.3.10 Seed Dormancy

Morro manzanita exhibits some seed dormancy; some viable seed does not germinate but instead persists over several years and perhaps decades despite the presence of appropriate environmental cues during the fall/winter seasons. Though research has not specially examined the dormancy mechanism for Morro manzanita seeds, congeners including *Arctostaphylos glandulosa, A. patula, A. uva-ursi* and *A. alpina* all exhibit physiological dormancy: a physiological inhibiting mechanism prevents germination of the seed even in the presence of appropriate environmental conditions (Baskin and Baskin 2001). This dormancy is likely overcome by warm and/or cold stratification (Keeley 1977, 1991, Baskin and Baskin 2001). These species are found in different habitats and not surprisingly, require different temperature regimes to break dormancy (Baskin and Baskin 2001).

Laboratory studies (Tyler et al. 1998, Tyler et al. 2000) indicated that there is not complete dormancy in Morro manzanita, since some seeds do germinate without any stratification, scarification, or treatment other than watering. Tyler et al. 2000 found 40% germination of viable seeds in controls. Seed treated with heat and charate to simulate the effects of fire germinated at a rate 80%, however.

B.2.3.11 Seed Bank

As a result of its dormancy, Morro manzanita has a seedbank—a population of viable seed in the soil and litter. A series of studies investigating the distribution and abundance of seed in the seedbank have found the following (Tyler and Odion 1996, Tyler et al. 1998, and Tyler et al 2000):

- 80% of seed occurred in the top 5 cm of the soil, and 20% in the lower 5 cm;
- 10 times more seed is found under the shrub canopy than 1.5 m away;
- a mean of 1,482 viable seeds/m^2 were observed across four sites, which varied greatly
- 35% fewer seeds were found under dead shrubs than live shrubs at the Elfin Forest;
- sites differed significantly in total seed in the seed bank;
- approximately 600 seeds/m^2 (not all viable) were added to the seedbank each year;
- sites vary in seed production and predation, and thus the amount of seed added to the bank; and,
- prescription fire greatly reduced the density of viable seed in the top 5 cm of the soil.

B.2.3.12 Seed Germination

Fire enhances Morro manzanita seed germination. Tyler et al. (2000) evaluated the combined effect of heat and charate--chemicals resulting from combustion of plant material--in overcoming dormancy and initiating Morro manzanita seed germination. They found that untreated, viable seed germinated at a rate of 40% while seed treated with heat and charate germinated at a rate of 80% (Tyler et al. 2000).

Morro manzanita germination was measured following a prescription fire (Tyler et al. 2000), though the lack of control plots limited the ability to evaluate the effects of fire on seed germination. Seedlings established at equal rates during the first two years following the prescription burn after which the plots were not monitored (Tyler et al. 2000). Other studies of fire in maritime chaparral have found no shrub emergence after the first year following fire, perhaps because the seed bank was exhausted by fire induced germination and mortality (Keeley 1991, Odion 2000, Odion and Davis 2000). Though the authors note that no studies have documented germination of obligate seeding species more than two years following fire (Tyler et al. 2000), they also suggest that seedling establishment occurred at rates lower than expected based on analysis of the post fire density of viable seed. In the absence of ongoing monitoring of the prescribed burn plots, it is not clear whether additional Morro manzanita seedlings may have established following the prescribed burn.

Like other obligate seeding species in the genus, *Arctostaphylos morroensis* may experience increased seed germination following fire. However, even in "refractory seed species", in which germination is triggered by an environmental stimulus, some of the seed crop is non-refractory; it will germinate without the stimulus (Keeley 1991). This could explain the low density of Morro manzanita seedlings observed in areas of the Bayview Unit of the Morro Dunes Ecological Reserve that have not likely burned in decades (J. McGraw, pers obs.).

B.2.3.13 Seedling Establishment

Though seeds of Morro manzanita can germinate in the absence of heat and charate under laboratory conditions (Tyler et al. 2000), very few young Morro manzanita are found in unburned areas. One exception is in an area that receives chronic soil disturbance due to recreation and associated erosion on the old Broderson Road in the Bayview Unit of the Morro Dunes Ecological Reserve. There, a stand of approximately 10 Morro manzanita that are juvenile to small adult (< 50 cm tall but reproductive) occur along a deep gully that presumably was caused by water erosion on the steep slopes of the former road (J. McGraw, pers obs.). It is possible that these individuals were planted as part of an informal restoration project; however, there has been no indication that this is the case.

These observations suggest that soil disturbance may create aspects of this fire-adapted species' regeneration niche. However, more research is needed to determine whether other disturbances can be used to successfully establish Morro manzanita seedlings. In a field experiment in another maritime chaparral system, *A. purissima* seedling establishment was enhanced by fire but not manual removal of shrubs, suggesting some aspect of fire (e.g., heat or charate) is required for germination (Tyler 1996). It is important to note that Morro manzanita seedling establishment may result in the absence of disturbances, as laboratory trials found that some seed germinated without treatments intended to remove the dormancy mechanism (Tyler et al. 1998, 2000).

Morro manzanita seedlings established even in sample plots that lacked adults prior to prescription fire (Tyler et al. 2000). Though none of the seedlings survived, their establishment itself surprised the researchers, given the low density of viable seed detected in soil cores obtained away from shrub canopies (Tyler et al. 1998).

B.2.3.14 Seedling Survival

Morro manzanita seedlings are highly susceptible to mortality. The first-year cohort (annual crop of seedlings) following fire exhibited 95% mortality over 1 year (March 1998 to March 1999); only 2 of the 41 sampled seedlings surviving the first year (Tyler et al. 2000). Survivorship was not monitored further, nor was survivorship of the second-year cohort examined.

Mortality was likely caused by several factors including desiccation stress and herbivory. Available soil moisture in the sandy soil is low throughout the year and may result in mortality during the long summer drought (May-October). Seedling mortality caused by herbivory by both large (deer) and small (rabbits) mammals might have also been a factor. The authors speculate that the small burn size may have resulted in unnaturally high levels of herbivory and thus seedling mortality. Trampling may have also reduced survival of small seedlings (Tyler et al. 2000).

B.2.3.15 Adult survivorship

No studies have examined the factors affecting survival of adult Morro manzanita; however, observations suggest that survivorship is high. In 1998, Tyler et al. observed mortality of adults in the Elfin Forest stand, which was hypothesized to be the oldest stand of Morro manzanita. However, it is not known whether this mortality is due to senescence or other site-specific conditions (e.g., disease). Mortality may increase as the stands age and individuals become more susceptible to disease.

B.2.4 Threats

B.2.4.1 Habitat Loss

As a narrowly distributed endemic species, Morro manzanita is threatened by habitat destruction. The loss of habitat due to conversion for development and agriculture has reduced the areal extent of the species by over 50% and fragmented remaining habitat patches (Tyler et al. 2000). As a result, the overall population of Morro manzanita has been reduced, and remaining populations are artificially small. Small populations face greater extinction risks due to environmental stochasticity (e.g., wildfire, drought, disease), Allee effects (reductions in population growth due to insufficient population size), and reduced fitness due to inbreeding depression.

Within protected habitat, populations of Morro manzanita are threatened by wildfire, fire exclusion, and exotic species.

B.2.4.2 Wildfire

Previous research found that Morro manzanita subject to prescription burning at Montaña de Oro State Park likely failed to re-establish at the pre-burn population density due to insufficient seedling establishment, likely because the return interval at the stand was too short to allow sufficient accumulation of viable seed (Tyler et al. 2000, Odion and Tyler 2002). These results suggest that frequent fires could reduce populations.

B.2.4.3 Fire Exclusion

The widespread exclusion of fire from the LOHCP Preserve System could also threaten persistence of Morro manzanita in the long term. Fire is the natural disturbance that promotes population regeneration. Morro manzanita seedlings do not appear to recruit in stand replacing densities in the absence of fire. Though it is not known at what age stands senesce, mortality of adult Morro manzanita will presumably increase at some time following fire. In the absence of fire, the canopy gaps created might be colonized by other species already present, including exotic plants, rather than recruiting Morro manzanita seedlings. Suppression of naturally occurring wildfire and avoidance of prescription fire as a management tool due to proximity of development may, in the long term, cause type conversion of Morro manzanita chaparral (e.g., to coast live oak woodland). The USFWS (2008) identified managing disturbance to regenerate and revitalize Morro manzanita populations as the primary issue for recovery of the species, after protecting habitat from conversion.

B.2.4.4 Exotic Plants

Exotic plant species threaten the persistence of Morro manzanita directly through competition, and indirectly, by altering abiotic conditions, rendering them unsuitable for Morro manzanita population persistence. Large, shade producing trees including eucalyptus (*Eucalyptus* spp.), and introduced conifers including Monterey pine (*Pinus radiata*) and Monterey cypress (*Callitropsis macrocarpa*) can outcompete seedling and adult Morro manzanita for both light and soil resources (e.g., water). Expansion of a eucalyptus grove in Montaña de Oro State Park has reduced the areal extent of Morro manzanita over the past 100 years (Tyler and Odion 1996). Though not currently invasive like eucalyptus, spp., Monterey pine and Monterey cypress are both fire adapted species and could increase their populations and further compete with Morro manzanita following fire or other disturbance (Tyler and Odion 1996, Tyler 1996).

Iceplants including *Carpobrotus* spp. and *Conicosia pugioniformis* are widespread through the coastal sage scrub communities and occur in canopy gaps with the Morro manzanita chaparral. Following wildfire or prescription burn, these species can spread and form dense mats that can compete with small, slowing growing Morro manzanita seedlings, thus precluding successful stand regeneration (D'Antonio 1990a, D'Antonio 1993, D'Antonio et al. 1993).

Like the iceplant species, veldt grass (*Ehrharta calycina*) may spread following fire and compete with Morro manzanita seedlings, reducing their establishment. In addition, the perennial grass will increase the density of fine fuel and, in doing so, might increase the frequency of fire, thus extirpating Morro manzanita. Annual grasses including red brome (*Bromus madritensis* ssp. *rubens*), ripgut brome (*Bromus diandrus*), and wild oats (*Avena* spp.) similarly threaten Morro manzanita populations, both by competing with seedlings for scarce soil resources and initiating a deleterious grass-fire cycle that can convert maritime chaparral to degraded grassland (D'Antonio and Vitousek 1992, Brooks 1999).

B.3 Indian Knob Mountainbalm (*Eriodictyon altissimum*)

B.3.1 Conservation Status

Indian Knob mountainbalm (*Eriodictyon altissimum* P. Wells; Boraginaceae) has been listed as endangered under both the California and federal endangered species acts and is ranked as most threatened and endangered according to the California Rare Plant Ranking (List 1B.1; CNPS 2016).

B.3.2 Available Information

There is little available information about the biology of Indian Knob mountainbalm (IKM). It was first collected in 1960 and described in 1962 (Wells 1962). No known research has examined the ecology of the species. The role of leaf resins in deterring insect herbivory of a widespread congener, yerba santa (*Eriodictyon californicum*) has been investigated (Johnson et al. 1985). The USFWS conducted a five-year review for this species in 2013, providing additional information about its ecology and conservation status (USFWS 2013a).

B.3.3 Distribution

Indian Knob mountainbalm is known from just seven occurrences in western San Luis Obispo County (CNDDB 2016). Two occurrences are on Indian Knob, an area south of San Luis Obispo and north of Pismo Beach. Two additional occurrences represented by a total of four, disjunct stands are in Hazard Canyon within Montaña del Oro State Park south of the LOHCP Area (USFWS 2013a). Of the three occurrences within the LOHCP Area, one is located in the Broderson site and the other two are within the Bayview Unit the Morro Dunes Ecological Reserve. A census of the three sites within the LOHCP in April 2016 found 22 individual plants (Occurrence 6) and 23 individual plants (Occurrence 4) in the two occurrences within the Bayview Unit; however, no Indian Knob mountainbalm plants were observed in the Broderson Unit (Occurrence 1; USFWS 2016). Though the populations range wide have not been comprehensively censused, they are estimated to total fewer than 600 plants, with most of those (~500) occurring within the Indian Knob occurrence approximately 13 miles east of Los Osos (USFWS 2013a). Indian Knob mountainbalm occurs on sandy soils derived from marine sandstone at Indian Knob and Pleistocene older and partly cemented aeolian deposits in the Los Osos Valley (i.e., Baywood fine sand). In both areas, Indian Knob mountainbalm occurs in vegetation characterized as a mosaic of chaparral and oak woodland. Within these communities, the distribution of Indian Knob mountainbalm is very limited; however, the microhabitat characteristics of the endangered shrub have not yet been examined. Observations at the Bayview Unit of the Morro Dunes Ecological Reserve indicates that remaining individuals are found in gaps along eroding trails within the otherwise contiguous canopy comprised primarily of Morro manzanita and coast live oak (J. McGraw, pers. obs.). More research is needed to determine the habitat characteristics required for persistence of IKM within the Los Osos region.

B.3.4 Biology

B.3.4.1 Morphology

Indian Knob mountainbalm is a tall (2-4 m) erect, evergreen shrub with diffuse branches. Its sticky stems support 5-9 cm long, narrow (2-4 mm wide) linear leaves with rolled margins that have a sticky upper surfaces and dense white hairs on their lower surfaces. Indian Knob mountainbalm produces lavender to whitish yellow tubular flowers that are 11-15 mm long and sparsely hairy. Its fruits are narrow capsules that produce small (ca. 0.4 mm long), brown seeds (Wells 1962, Hickman 1993).

While Indian Knob mountainbalm has an inflorescence that is morphologically similar to that of *Eriodictyon californicum*, the endangered shrub has rolled leaves that do not resemble that of its more widespread congener. Instead, the leaves are similar to that of Lompoc yerba santa (*Eriodictyon capitatum*), which has a very different inflorescence. Despite these morphological similarities, Indian Knob mountainbalm is not thought to be a hybrid of the two other species (Wells 1962), with which it does not co-occur.

B.3.4.2 Phenology

Indian Knob mountainbalm flowers in early summer (June-July) and develops fruit in late summer and early fall. There is no available information about other aspects of the species phenology. As with other shrubs in California’s Mediterranean climate, seeds of Indian Knob mountainbalm likely germinate with the onset of the rains between October and December, though this has not been documented.

B.3.4.3 Life History

Indian Knob mountainbalm is a polycarpic perennial shrub. Based on observations of slow-growing lichens attached to its stems, IKM is thought to be long-lived (USFWS 1998a), though no estimates for its life span are available. The small size of colonies suggests current individuals are survivors of once larger populations; however, there is no information about historic population densities. The age or size of shrubs at the onset of reproduction is currently unknown.

B.3.4.4 Vegetative Reproduction

Indian Knob mountainbalm appears to be able to establish additional ramets (i.e., clones) from root sprouts (Wells 1962). This form of vegetative reproduction has important implications for population persistence by influencing regeneration following disturbance, and genetic diversity. Following fire, IKM may be able to re-establish from below-ground tissues that remain. Removal of aboveground parts combined with changes in abiotic and biotic conditions following fire may increase the rate at which new ramets ('clones') are produced from the root structures of current individuals.

Because it can spread vegetatively, multiple plants observed within a given occurrence may be part of the same genet or genetically unique individual. If this is the case, and if IKM is self-incompatible, then uniclonal patches may not be able to regenerate from seed, at least not substantially so, unless viable seed remains within the seed bank. Clumped plant distributions can result not only from clones developing from common root structures, but also limited seed dispersal and higher rates of establishment and survival in appropriate habitat conditions, which tend to be spatially autocorrelated (i.e., clumped). As a result, it is not possible to determine whether individual ramets observed within remaining stands are genetically distinct individuals, without perhaps destructively examining their underground structures.

Vegetative reproduction of IKM also has potentially importance for the genetic diversity and resulting persistence of the species. If IKM requires fire to reproduce sexually, the remaining small populations are comprised of one or a few genets that have survived in the absence of fire, and there is no viable seed bank, then the populations may have gone through narrow genetic bottlenecks. Such reductions in genetic diversity might reduce future population viability, even following successful management to increase establishment and thus population abundance.

There is no information available about the factors which influence vegetative reproduction in the species, such as the age or stage of the parent plant, the habitat conditions, or role of disturbances such as fire in initiating formation of a new ramet. Based on observations of high density, vigorous stands along road cuts at Indian Knob, Wells (1962) hypothesizes that the species is disturbance-dependent for its regeneration, though does not specify whether establishment in disturbed areas occurs exclusively from seed.

B.3.4.5 Sexual Reproduction

Reproduction

Indian Knob mountainbalm plants are perfect flowers (i.e., they feature both stamens and a pistil). It is not known whether these flowers can self-pollinate. It is also not known whether the species is self-incompatible; that is, if the ovary of a given individual plant cannot produce viable seed when fertilized by pollen from the same plant. Self-incompatibility has been documented for the narrow-leaved congener endemic to Santa Barbara County, Lompoc yerba santa (*Eriodictyon capitatum*) (Elam 1995).

Pollination Biology

There is no specific information available about the pollination biology of IKM. The recovery plan for the species reports that "a variety of non-specialist, potentially pollinating insects have been recovered visiting the flowers of this species"; however, there is no additional information about the insects, the study, or the observers (USFWS 1998a).

Seed and Seedling Biology

Due to their low weight (0.2 mg), IKM seeds are hypothesized to be wind dispersed (Wells 1962). Based on its association in fire-prone chaparral communities, its ability to regenerate from belowground structures following fire, its low abundance or perhaps absence of seedling and juveniles within remaining stands, and its high abundance along roadsides and other disturbed areas (Wells 1962), it is hypothesized that Indian Knob mountainbalm requires disturbance, specifically fire, to stimulate seed germination and/or create habitat conditions required for seedling establishment. Research is needed to determine the regeneration niche of Indian Knob mountainbalm and the potential role of fire and fire surrogates in facilitating recruitment within these aging populations.

John Chesnut, a biologist from the Los Osos region, is quoted in the recovery plan as indicating that IKM exhibit that low seed set (USFWS 1998a); however, there is no information about the nature of the observations. Low seed set is consistent with self-incompatibility in small populations comprised of one or just a few genets (as described below). Low seed set can also result from insufficient pollinator visitation, which can be problematic in small populations of plants that require specialist pollinators.

There is no information available about IKM seed predation, seed viability, seed dormancy, seed germination, or seed bank dynamics.

B.3.5 Threats

B.3.5.1 Habitat Loss

Indian Knob mountainbalm is threatened by habitat loss. Though its original distribution within the Los Osos Valley is unknown, the species' populations very likely have been reduced due to habitat destruction, which has reduced the areal extent of central maritime chaparral communities (Tyler et al. 2000). Habitat conversion for development and agriculture has also fragmented remaining habitat patches, thus reducing the size of remaining populations and increasing their extinction risks due to environmental stochasticity (e.g., wildfire, drought, disease), Allee effects (reductions in population growth due to insufficient population size), and reduced fitness due to inbreeding depression.

Within protected habitat, IKM populations are threatened by fire exclusion, exotic species, recreation, and perhaps a wildfire.

B.3.5.2 Fire Exclusion

The widespread exclusion of fire has likely reduced the distribution and population abundance of IKM and may have contributed to the likely extirpation of two of the three occurrences within the LOHCP Area (USFWS 2013a). Remaining occurrences are restricted to gaps within otherwise contiguous shrub cover and consist of a low number of individuals (USFWS 1998a, 2013), many of which may be senescent as indicated by sparse leaves confined to branch tips that were observed even during Wells initial description of the species (Wells 1962). As a natural part of the disturbance region in the region, fire is likely required to facilitate both sexual and vegetative reproduction of IKM. In the absence of fire, canopy gap closure may occur, thus creating unsuitable conditions for remaining plants, many of which may be susceptible to mortality due to disease, herbivory, or senescence. Suppression of naturally occurring wildfire and avoidance of prescription fire as a management tool due to proximity of development may cause the extirpation of the remaining stands.

B.3.5.3 Exotic Plants

Exotic plant species may threaten the persistence of IKM directly through competition, and indirectly, by altering abiotic conditions, rendering them unsuitable for the species. Large, shade-producing trees including eucalyptus (*Eucalyptus* spp.) and introduced conifers such as Monterey pine (*Pinus radiata)* and Monterey cypress (*Callitropsis macrocarpa*) reduce light availability for IKM, which is likely adapted to the open canopy conditions characteristic of early successional chaparral. These trees may also compete with seedling and adult IKM for soil resources, including water which can be scarce in the sandy soils.

Iceplants, including *Carpobrotus* spp. and *Conicosia pugioniformis,* are widespread through the coastal sage scrub communities in the Los Osos area and occur in canopy gaps with the Morro manzanita chaparral. Following wildfire or prescription burn, these species can aggressively invade and form dense mats that might compete with small, slowing growing IKM seedlings, thus precluding successful stand regeneration (D'Antonio 1990a, 1993, D'Antonio et al. 1993).

Like the iceplant species, veldt grass (Ehrharta calycina) may spread following fire and compete with IKM seedlings, reducing their establishment. In addition, the perennial grass will increase the density of fine fuel and, in doing so, might increase the frequency of fire, thus extirpating IKM. Annual grasses including red brome (Bromus madritensis ssp. rubens), ripgut brome (Bromus diandrus), and wild oats (Avena spp.) similarly threaten IKM populations, both by competing with seedlings for scarce soil resources and initiating a deleterious grass-fire cycle that can convert maritime chaparral to degraded grassland (D'Antonio and Vitousek 1992, Brooks 1999).

B.3.5.4 Recreation

The Indian Knob mountainbalm stand within the Bayview Unit of the Morro Dunes Ecological Reserve is located along a trail. In the absence of fire, the chronic disturbance due to recreational use may maintain the open canopy conditions required for IKM persistence within the otherwise closed-canopy central maritime chaparral and coast live oak woodlands. However, recreation can negatively impact remaining individuals through direct trampling and through soil compaction, which may preclude vegetative reproduction from roots. Due to the low density and senescence of remaining individuals, it is important that all potential threats be addressed to preclude population extirpations and ultimate extinction.

B.3.5.5 Wildfire

A large wildfire may threaten persistence of IKM if conditions of the fire reduce regeneration from seed and/or suckers. There is no current evidence to suggest the species is susceptible to decline as a result of fire; however, given the small geographic range and low density of remaining populations, a conservative approach to management should include prevention of wildfire.

B.4 Morro Bay Kangaroo Rat (*Dipodomys heermanni morroensis*)

B.4.1 Conservation Status and Planning

The Morro bay kangaroo rat (*Dipodomys heermanni morroensis*) is federally and state-listed endangered species (USFWS 1970) and is also a California fully protected species (CDFW 2016). The USFWS released a Draft Revised Recovery Plan for the Morro Bay Kangaroo Rat (USFWS 1999). The USFWS also designated critical habitat for the Morro Bay kangaroo rat (USFWS 1977).

B.4.1.1 Recovery Plan

The objective of the draft revised recovery plan for Morro Bay kangaroo rat is to down list the species to threatened; the limited amount of remaining historic habitat will likely preclude delisting. The down listing criterion is to have effective genetic population size of 500, which equals approximately 2,000 individuals. Actions needed to achieve this include:

1. Establish a captive breeding program with 100 individuals removed from the wild;
2. Secure, manage, and improve habitat for all available areas of historic habitat; and
3. Reintroduce captive-bred individuals into the restored habitat.

These actions reflect the fact that the species has not been detected since 1991 (USFWS 1999) and has not been observed in the wild since 1986 (USFWS 2011b).

B.4.1.2 Critical Habitat

In 1977, the USFWS designated critical habitat for Morro Bay kangaroo rat within a single 689-acre unit that includes the southern portion of the Morro Bay sand spit and adjacent habitat west of Pecho Valley Road (Figure 4-3); specifically, the southern half of section 14 and portions of Sections 23 and 24 west of Pecho Valley Road in T30S R10E of the Mount Diablo Base and Meridian.

Of the 672 acres contained within parcels (the remainder is outside of the parcel GIS database), 629 acres (94%) of the critical habitat area is protected within the Morro Dunes Ecological Reserve and the northern portion of Montaña de Oro State Park, much of which is designated as part of the Morro Dunes Natural Preserve (Figure 4-3).

B.4.2 Description and Taxonomy

A member of the gopher family (Heteromyidae), Morro Bay kangaroo rat is a small rodent with external cheek pouches, large hind legs, relatively small front legs, a long tail, and a large head. It is one of nine subspecies of Heermann's kangaroo rat (*Dipodomys heermanni*); when compared with the other subspecies, Morro Bay kangaroo rat is small and more darkly colored (USFWS 1999).

B.4.3 Historic Distribution

The Morro Bay kangaroo rat is endemic to the Baywood fine sands ecosystem centered on the community of Los Osos in coastal San Luis Obispo County. Its range does not overlap that of the other nine subspecies of *D. heermanni*, the nearest of which occurs in eastern San Luis Obispo County (USFWS 1999).

In 1948, Morro Bay kangaroo rats were thought to occupy a 4.8 square-mile area, within which 2.2 square miles provided suitable habitat; the remaining area featured dense trees, thick chaparral, or were developed (Stewart 1958). By 1971, Morro Bay kangaroo rat was known from just six localities totaling 183 acres on the current perimeter of the community of Los Osos (Congdon 1971, and Congdon and Roest 1975). In 1989, the total area occupied by Morro Bay kangaroo rat was estimated to be 37 acres distributed within what is now the Bayview Unit of the Morro Dunes Ecological Reserve. The species was last observed there in 1990 and 1991 (USFWS 1999).

B.4.4 Habitat

Within the Baywood fine sands ecosystem, Morro Bay kangaroo rat habitat includes compacted sandy soils with slopes of less than 15 degrees, supporting a range of vegetation types (Gambs and Holland 1988). Morro Bay kangaroo rats are believed to have occupied a large portion of the area currently or historically covered by the coastal sage scrub on the older and more stabilized dunes. Within this community, Morro Bay kangaroo rat was preferentially observed in early successional areas characterized by lower plant species diversity, scattered areas of bare ground, greater cover of wedge-leaf ceanothus (*Ceanothus cuneatus*), deerweed (*Acmispon glaber*), and wedgeleaf horkelia (*Horkelia cuneata*), lower cover of yarrow (*Achillea millefolium*), iceplant (*Carpobrotus spp*.), California aster (*Corethrogyne filaginifolia*), and dudleya (*Dudleya caespitosa*), and moderately sparse cover of California sagebrush (*Artemesia californica*), black sage (*Salvia mellifera*), mock heater (*Ericameria ericoides*), and dune lupine (*Lupinus chamissonis;* USFWS 1999).

B.4.5 Activity and Behavior

Morro Bay kangaroo rats inhabit burrow systems that they use for nesting, escape, and caching seeds, their primary food source. They are largely solitary and share burrows only for purposes of mating or rearing pups. Nocturnal, they emerge from underground burrows immediately after dusk and then periodically throughout the night until one to two hours before dawn. Morro Bay kangaroo rats breed between March and August (Gambs and Holland 1988). They remain fairly close to their main burrows and rarely disperse. Observed dispersal distances have been less than 1,500 feet (USFWS 1999).

B.4.6 Feeding

The Morro Bay kangaroo rat primarily forages by shuffling its front feet through the sand in search of seeds; the species also grabs foliage, flowers, or fruits directly from plants. Food items are either eaten or placed into the cheek pouches, from which materials are either horded in the burrow or hidden in small surface-pit- caches.

B.4.7 Threats

Declines in Morro Bay kangaroo rat have been attributed to two primary factors: habitat loss due to development within the Los Osos and Baywood Park communities, and fire exclusion, which converts early-successional coastal sage scrub habitat to later successional communities that lack the preferred food plants and perhaps other important structural components of their habitat. Mowing, grading, off-road vehicles, equestrians, trail use, and invasive exotic species also degrade habitat. Predation by domestic and feral cats and dogs, fragmentation of larger populations into small subpopulations, and perhaps inbreeding depression may have also contributed to the decline in the Morro Bay kangaroo rat (USFWS 1999). Morro Bay kangaroo rat may also be susceptible to mortality caused by rodenticides.

B.4.8 Results of Recent Surveys

Morro Bay kangaroo rat has not been detected during surveys conducted since 2004 (Table B-1). These surveys, which have included visual surveys for sign (e.g., tail drags marks, foot prints, and droppings), live trapping, and use of scent-detection dogs, have been conducted within the species historic range on public lands as well as private lands where access has been permitted. The species may persist in unsurveyed, privately held parcels, at densities below detectable levels, or perhaps in sandy soil areas east and south of the LOHCP Area (Villablanca 2009, USFWS 2011a).

Table B-0-1: Recent surveys for Morro Bay Kangaroo rat in the LOHCP Area

Survey	Methods	Location(s)	Results
Pre-Project Surveys for the Los Osos Wastewater Treatment Plant (Villablanca 2004)	Habitat Assessment and Pedestrian Transect (Visual) Survey	Broderson and Midtown Sites	Suitable habitat is present at Broderson but not Midtown (but see Villablanca 2010); no sign of MBKR detected at either site
Protocol Surveys for MBKR (Villablanca 2009)	Phased Approach: Habitat Assessment, then Visual Survey if habitat assessment positive, and the Live Trapping where visual survey positive.	Montaña de Oro State Park, Morro Dunes Ecological Reserve, Los Osos Oaks Preserve, Morro Bay State Park, and four private lands	Suitable habitat present, though fragmented and degraded; no MBKR observed in 948 trap night effort at 7 sites
Midtown Assessment and Survey (Villablanca 2010)	Habitat Assessment and Pedestrian Transect (Visual) Survey	Midtown	Suitable habitat present (previous assessment that habitat not suitable was revised) but no MBKR sign detected
Recovery Surveys (USFWS 2011c)	Live Trapping	Morro Bay State Park near Santa Ysabel, and Montaña de Oro State Park and Pecho Unit of the Morro Dunes Ecological Reserve	No MBKR observed in 1,668 trap nights
Scent-Detection Dog Searches (USFWS 2016)	Searches by scent-detection dogs trained to detect Lompoc kangaroo rat (*Dipodomys heermanni arenae*)	Montaña de Oro State Park, Morro Bay State Park, and the Morro Dunes Ecological Reserve	Two 'alerts' by scent dogs during the three-day search. Bait stations with cameras subsequently set at alert sites. No MBKR were detected in the belt/camera stations, which were operated for 12 non-consecutive weeks.