5-YEAR REVIEW

Pacific Pocket Mouse
(*Perognathus longimembris pacificus*)

GENERAL INFORMATION

Species: Pacific Pocket Mouse (*Perognathus longimembris pacificus*)

Date listed: September 29, 1994

FR citation(s): USFWS 1994 (59 FR 49752)

Classification: Endangered

Associated Rulemakings: Pacific pocket mouse (*Perognathus longimembris pacificus*; PPM) was emergency listed as endangered on February 3, 1994 (59 FR 5306–5310). The emergency listing remained in effect until September 28, 1994, when the species was listed as endangered. No critical habitat has been designated for this species.

Methodology used to complete the review: In accordance with section 4(c)(2) of the Endangered Species Act of 1973 (Act), as amended, the purpose of a 5-year review is to assess each threatened species and endangered species to determine whether its status has changed and it should be classified differently or removed from the Lists of Threatened and Endangered Wildlife and Plants. The U.S. Fish and Wildlife Service (Service, we) prepared a Species Biological Report (USFWS 2020) to evaluate the biology and status of PPM and inform this 5-year review. We used information from the scientific literature, surveys and reports, previous rulemakings, the Recovery Plan, and the 2010 5-year review. We also considered information received in response to the initiation of the 5-year review. This 5-year review summarizes information through 2019 from the Species Biological Report, and analyzes current threats to PPM that are attributable to the Act's five listing factors. This review also evaluates the listing status of the species, evaluates progress towards recovery, and recommends priority conservation actions to be completed or initiated within the next 5 years.

FR Notice citation announcing the species is under active review: USFWS 2018 (83 FR 28251); Endangered and Threatened Wildlife and Plants; Initiation of 5-year Status Reviews of 50 Species in California, Nevada, and the Klamath Basin of Oregon; June 18, 2018. We received information about the Pacific pocket mouse from the Center of Natural Lands Management and incorporated relevant information as appropriate.

REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) policy:

The Endangered Species Act defines "species" as including any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate wildlife. This definition of species under the Act limits listing as distinct population segments to species of

vertebrate fish or wildlife. The 1996 Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Endangered Species act (USFWS 1996, pp. 4722–4725) clarifies the interpretation of the phrase "distinct population segment" for the purposes of listing, delisting, and reclassifying species under the Act. PPM is not listed as a DPS, and there is no new information to suggest that this subspecies should be listed as a DPS.

Biology and Habitat

Since the 2010 5-year review, new research has examined PPM diet (Iwanowicz *et al.* 2016, entire; Harvey 2018, entire; King *et al.* 2018, entire), interspecific competition (Chock *et al.* 2018, entire), cache pilfering (Chock 2018, entire; Chock *et al.* 2019, entire), reproductive behavior/communication (Sheir *et al.* 2016, entire; King *et al.* 2018, entire), and genetics (Wilder *et al.* 2020, entire). In partnership with the Service and the California Department of Fish and Wildlife (CDFW), the San Diego Zoo Institute for Conservation Research (SDZ-ICR) established a captive rearing program for PPM, and reintroduction efforts are ongoing at one site in Laguna Coast Wilderness Park (LCWP) in Orange County, California. Additionally, live trapping and track tube surveys were performed to monitor the status and trends of each of the extant populations. Data from multi-year monitoring on Marine Corps Base Camp Pendleton (MCBCP) has been used to model biotic and abiotic factors associated with PPM habitat suitability and habitat patch level extinction/colonization dynamics (Brehme *et al.* 2018, entire).

This section summarizes new information about PPM biology and habitat associations learned since the 2010 5-year review. Refer to the Species Biological Report for a complete discussion of new PPM information (USFWS 2020a, entire).

Diet

In the 2010 5-year review, we discussed early observations by von Bloeker (1931, p. 371) and Bailey (1939, p. 327) of seeds in PPM cheek pouches, as well as a field study by Meserve (1976, entire).

Since 2010, PPM diet has been studied by Iwanowicz *et al.* (2016, entire), Harvey (2018, entire), and SDZ-ICR. Iwanowicz *et al.* (2016, pp. 15–16) found that PPM used both native and nonnative food plants (although forb species were dominant in the diet analysis), and detected seasonal and site differences in PPM diet. Harvey (2018, entire) studied dietary preferences of captive PPM, examining preferences for native or nonnative seed, whether dietary preferences were predicted by seed nutrition, and the effects of seed exposure at different stages of development. This study suggests that pre-weening exposure can influence an individual's foraging behavior (Harvey 2018, pp. 20–22). SDZ-ICR staff analyzed the nutrient content of seeds from native plant species that could be important for PPM, developed supplemental feeding guidelines for captive PPM (King *et al.* 2018, pp. 5–7), and examined differences in preference for native seeds between wild-caught and captive-born PPM (Shier *et al.* 2016, pp. 39–42).

Behavior

Foraging and Torpor

In the 2010 5-year review (pp. 6–7), we discussed adaptations of PPM that allow it to go through long periods of dormancy below ground (e.g., winter hibernation, summer aestivation), such as its seed caching behavior and capacity to use torpor to reduce metabolic energy demands, presumably in response to environmental stresses of food shortages and/or low temperatures (Bartholomew and Cade 1957, p. 71; Chew *et al.* 1967, entire; Kenagy 1973, pp. 1212–1218; Meserve 1976, pp. 312–317). Phenological monitoring has since shown that dormancy in PPM varies spatially and temporally, with components of the populations in close proximity to one another sometimes emerging and/or entering dormancy at different times within years. The length of surface activity varies among years, with PPM sometimes emerging as early as February, and/or remaining active until as late as December (Brehme *et al*. 2018, p. 37). While prolonged surface activity can be indicative of prolonged reproduction and population growth (Miller and Pavelka 2008, pp. 63–64), extended surface activity may not always represent prolonged reproduction. In 2017, Brehme *et al.* (2018, p. 41) observed PPM at one location cease reproductive activity by mid-June, but remain active until mid-December.

To understand whether PPM foraging and seed caching behavior helps to promote its co-existence with other small mammals, Chock (2018, thesis and Chock *et al.* 2019, entire) studied whether PPM pilfer from seed caches of co-occurring rodent species (or vice versa), and whether the rodents use scent to find or avoid caches (Chock *et al.* 2019, p. 1608). They found that little pocket mice—PPM and Los Angeles pocket mouse—pilfered more from larger heterospecifics (2 of 10) than heterospecifics pilfered from little pocket mice (1 of 33), but that overall, rates of pilfering by little pocket mice were low (p. 1613).

Communication

Heteromyids use sandbathing as a way to clean their fur, and as a form of chemical communication (Eisenberg 1963, p. 21). Shier *et al.* (2016, entire) studied whether female PPM communicated reproductive condition (estrus) using sandbathing. They found that female PPM in estrus spent more time investigating male-scented sand than female-scented sand, and there were no differences in responses (i.e., time spent investigating male-scented sand, and frequency and duration of sandbathing) of wild-caught versus captive-born females (Shier *et al.* 2016, p. 22).

Social structure

PPM are solitary and nonsocial. Observations from the captive breeding program reveals that PPM, particularly female PPM, display aggression to male conspecifics during breeding events (King *et al.* 2018, p. 12).

Chock *et al.* (2018, entire) studied competition between PPM and four other native rodent species of San Diego coastal sage scrub habitat. Body size differences strongly predicted dominance: three of the four rodent species—all with larger body sizes—were dominant over PPM, while one rodent (western harvest mouse) with a similar body size did not differ from

PPM in dominance index (Chock *et al.* 2018, p. 201). PPM actively avoided all species except western harvest mouse (p. 201).

Over 6 years of PPM monitoring at MCBCP, the presence of other rodent species negatively affected the probability of detecting PPM (Brehme *et al*. 2018, p. 26)

Reproduction

PPM gestation typically lasts 23.3 days, and young are weaned after 30 days (Shier *et al.* 2016, pp. 18 and 31). *Perognathus longimembris* become sexually mature at 41 days of age and can breed in their natal year during favorable conditions (Hayden *et al.* 1966, p. 416; Miller and Pavelka 2008, pp. 28–29). Female PPM may begin estrus as early as 37 days of age, and males may become scrotal or partially scrotal at 42 days of age (Shier *et al.* 2016, p. 14).

Since 2010, the PPM captive breeding program has studied PPM reproduction extensively; refer to the Species Biological Report for a complete discussion.

Territory, Home Range, and Movement

Our discussion of PPM territory, home range, and movement from the 2010 5-year review is still relevant. As discussed in detail in that review (pp. 9–11) and in the Species Biological Report (USFWS 2020, pp. 11–13), mean observed range length (ORL) is significantly different between male and female PPM. Over a 4-year monitoring period, mean ORL was 29.3 and 17.9 meters (96.1 and 58.7 feet) for males and females, respectively. Some PPM were observed to go on longer distance excursions, and relocate to different areas within the monitoring grids.

Spatial Distribution

In 2010, PPM was considered still extant at four sites: one site on the Dana Point Headlands in Orange County, managed by the Center for Natural Lands Management (CNLM), and three sites on Marine Corps Base Camp Pendleton in San Diego County (San Mateo North, San Mateo South, and Santa Margarita). However, at the time of the 5-year review, it was suspected that the San Mateo North population could be extirpated, as PPM had gone undetected during several surveys performed at this locale since 2003, when PPM were last captured there (Natural Resources Assessment 2003, p. S-1; Montgomery 2005, p. 25; Brehme and Fisher 2009, pp. 3, 17; USFWS 2010, pp. 22, 65–66). Four additional surveys performed at San Mateo North since the 5-year review (Brehme *et al.* 2014, pp. 17, 14; Brehme *et al.* 2018, p. 4) did not detect PPM, increasing the likelihood and supporting the presumption that this population is extirpated. Accordingly, just three PPM occurrences are now believed to remain extant in the wild, with all other historical locations considered to be extirpated.

As a component of the Marine Corps Base Camp Pendleton PPM monitoring program, a portion of annual survey effort is directed towards the discovery of additional unknown populations on Base. During 2016, PPM tracks were observed on track cards from three track tubes deployed along a transect placed in the Oscar Two training area (Brehme *et al.* 2017, p. 39). Follow up live-trapping subsequently captured a single PPM in this vicinity. Another unrelated live-trapping

survey performed in Oscar Two the following year captured a single male PPM along Aliso Canyon Road, in the vicinity of a former shooting range within Oscar Two and about 1.5 kilometers (0.9 miles) north of the 2016 detections (GSRC 2017, p. 9). However, this location was disturbed by road maintenance grading shortly thereafter and no additional PPM were detected in the vicinity (GSRC 2017, p. 9).

The Oscar Two training area lies immediately to the northwest of Aliso Canyon Road, which is the border with the Edson Range training area (where the Santa Margarita PPM population is distributed to the south). To better characterize the distribution of PPM in the Oscar Two training area, in 2017 and 2018 additional track tube discovery transects and grids were placed in the vicinity of the Oscar Two PPM detections (Brehme *et al.* 2018, pp. 1, 2, 11). However, no additional PPM detections were made during these surveys. Thus, it is not clear if the 2016 and 2017 PPM detections in Oscar Two represent a portion of the range of the species that previously had not been documented, or are chance detections of animals dispersing from the Santa Margarita population in search of suitable habitat elsewhere. Monitoring of the Santa Margarita population reveals that PPM habitat use within Edson Range was steadily increasing between 2012 and 2016 (Brehme *et al.* 2018, pp. 22, 43), so these detections are consistent with an expansion in the range of a growing population.

As discussed below, the release of captively bred PPM at LCWP in Orange County was initiated in 2016, and is still being pursued in an attempt to create a fourth population in the wild. However, due to observed low over-winter survivorship of released individuals, this effort has not yet established a fourth viable self-sustaining population at this locale.

Habitat Use, Abundance and Survivorship

Efforts to document the abundance of PPM populations have revealed that intensive survey efforts are needed to estimate abundance of PPM, due to low individual detection probabilities, the patchy distribution of mice across large areas of heterogeneous habitat suitability, and spatial and temporal variability in abundance. Because this level of effort is not feasible to implement within all but the smallest PPM population, efforts to track trends of the extant populations primarily focus on estimating the extent of annual habitat use by PPM within the known occurrences, as an index of underlying population dynamics.

Since 2012, the U.S. Geological Survey (USGS) has been annually monitoring the status of PPM on MCBCP using a site occupancy statistical framework (MacKenzie and Royle 2005, entire). The monitoring protocol uses tracking tubes deployed in randomly placed 1-hectare grids to sample and estimate annual habitat use within monitoring boundaries delineated for each of the extant populations. Track tubes are a cost-effective method for monitoring PPM activity due to the ability to deploy large numbers of tubes within an area for an extended period of time without the need to check their contents on a daily basis (Brehme *et al.* 2010, p. 41). However, because more than one PPM has potential to leave tracks within a tube, this monitoring protocol is not well suited for abundance estimation.

A 13 hectare [ha; 32 acres (ac)] area has been delineated for monitoring the North San Mateo population; however, PPM have not been detected at this location since 2003 (Natural Resources

Assessment 2003, p. S-1), suggesting this population may be extirpated (USFWS 2010, pp. 22–23, 61–64; Brehme *et al*. 2014, p. 1; Brehme *et al.* 2019, pp. 7, 18). At South San Mateo, between 2012 and 2019 the estimated amount of habitat used by PPM has averaged 32.4 ha (80 ac) [range 20.2–43.8 ha (50–108 ac)], or about 31 percent of the 105 ha (259 ac) area that is monitored as potential habitat (Brehme *et al*. 2018, p. 22). The Santa Margarita population spans two troop training areas with different training regimes and operational restrictions, so the monitoring program estimates habitat use separately within the Edson Range and Oscar One training area portions of the Santa Margarita population. Within the 474-ha (1,171 ac) area delineated as potentially occupied by PPM within the Edson Range, estimated habitat use between 2012 and 2019 has averaged 174 ha (430 ac) [range 70.2–281.6 ha (173.5–696 ac)], which represents about 37 percent of the monitored area. Within the 411-ha (1,016 ac) area delineated for PPM monitoring within Oscar One, estimated habitat use between 2012 and 2019 has averaged 39 ha (96 ac) [range 9.7-67.8 ha (24.0–167.5 ac)] representing about 9 percent of the monitored area.

Combined, in 2019, the estimated habitat use for all populations on Base was estimated to be 118 ha (292 ac), representing a 47 percent decline from 2018, and the lowest estimate of habitat use since monitoring began in 2012 (Brehme *et al.* 2019, p. 13). This is a 65 percent decrease from the peak on Base habitat use estimate of 335 ha (828 ac) measured in 2016 (Brehme *et al.* 2019, p. 13).

Monitoring of PPM within the 11.9 ha (29.4 ac) Dana Point Preserve is performed using a combination of track tube and live trapping surveys (Merrill 2019, p. 1). Here, track tube monitoring is performed on an annual basis, within almost all suitable habitat within the Preserve to estimate habitat use, and live trapping data is collected intermittently (e.g., once every 3-5 years) to obtain complementary data on abundance. Monitoring of PPM within the Dana Point Preserve suggests that after an expansion in habitat use and abundance—which occurred following the creation of the Preserve and inception of active habitat management in 2005—the Dana Point PPM population has recently undergone a population decline and is highly vulnerable to extirpation from isolation and small population size. At its peak, within the 7.24 ha (17.9 ac) of suitable habitat within the Preserve that are monitored, live trapping detected 82 PPM (Brylski *et al.* 2010, p. 7), and mice were estimated to be using around 81 percent (range 73–87 percent)[1] of the available habitat (Carranza 2014, p. 15). However, a comprehensive live- trapping effort performed throughout the Preserve in 2017 detected just 6 individuals (Miller 2017, p. 3), and the use of available habitat within the Preserve by PPM was estimated to have declined to about 1.05 ha (2.59 ac) or 14.5 percent [95 percent Confidence Interval (C.I.), 6.68–28.52 percent] of the monitored habitat in 2019 (Merrill 2020, entire). Onsite protections implemented by CNLM to protect PPM habitat include management of coastal sage scrub, management of visitor impacts, and the use of fencing to protect around the land boundary (Merrill and Rogers 2019, pp. 23–24).

Although there are significant logistical challenges to reliable demographic population estimation for PPM, analysis of genetic samples collected during population monitoring can be used to estimate the effective size (N_e) of a population (i.e. the number of individuals in a population that contribute genes to the next generation), which provides important data for assessing the genetic health of a

[1] All ranges provided are calculated using a 95 percent C.I.

population. As a rule of thumb, for long term genetic health of isolated populations, each population should support, at minimum, an N_e of 50 to minimize the potential for inbreeding depression (i.e., reduced fitness from mating of closely related individuals), and an N_e of 500 to maintain genetic variation and the potential to adapt to changing environmental conditions over the long term (Frankham *et al.* 2014, pp. 341–345). Analysis of genetic samples collected during population monitoring suggest that effective population sizes within the extant PPM populations are universally low and cause for concern. The estimated effective population sizes are: N_e=3.3 (95 percent C.I.=2.2-7.4) at Dana Point, N_e= 25.0 (95 percent C.I.=15.7-47.1) at South San Mateo, and N_e=50.6 (95percent C.I.=43.1-60.0) at Santa Margarita (Wilder *et al.* 2020, unpaginated).

Habitat and ecosystem

Our 2010 discussion (USFWS 2010, pp. 34–37) of PPM habitat and ecosystem remains accurate, but habitat modeling by Brehme *et al.* (2018, entire) has provided new information about environmental predictors of local scale PPM habitat use, colonization, and extinction.

As we discussed in 2010, the Dana Point and San Mateo South occurrences are distributed mostly within areas vegetated with coastal sage scrub. The Santa Margarita population occurs across an area of intermixed sage scrub and grassland/forblands, and portions of this occurrence have relatively little shrub cover. Within these vegetation associations, PPM needs sparsely vegetated areas and small open patches. PPM is typically not found in areas covered by dense nonnative grasses and thatch (USFWS 2010, pp. 34–37); modeling by Brehme *et al.* found that increased nonnative grass cover was a strong predictor of decreased colonization and increased extirpation (2018, p. 27). Moderate to high forb cover (between 40 and 80 percent) and moderate to high open ground (between 20 to 70 percent) were also top predictors of PPM occupancy across all sites (Brehme *et al.* 2018, p. 27).

Genetics

In 2010, we discussed Swei *et al.* (2003, pp. 501–514), who studied the genetic structure of historical and extant PPM populations. They looked at haplotype genetic diversity (distinct mitochondrial genotypes, which indicate maternal genetic diversity) within historical museum specimens and animals captured within the extant populations between 1995–2002, and found a pattern of genetic variation indicating the extant populations are differentiated from one another, and were likely isolated prior to the post World War II urbanization of Southern California. Swei *et al.* (2003) also found the Dana Point population had low haplotype diversity in comparison to other PPM populations.

Using genetic samples collected between 2003 and 2018, Wilder *et al.* 2020 (unpaginated) studied contemporary nuclear and mitochondrial genetic variation within the extant and captive populations. They found that contemporary effective population sizes within all of the extant populations are extremely low (i.e., $N_e < 51$) (Wilder *et al.* 2020, unpaginated), and below what is considered necessary for sustaining genetic variation over the long term (Frankham *et al.* 2014). They also found a striking loss of mitochondrial haplotype diversity relative to that reported by Swei *et al.* (2003, pp. 505–506), suggesting that all populations have undergone a recent reduction

in population size. While all populations have suffered a significant loss of genetic diversity, the Dana Point population has suffered the greatest losses, with only 1 of 9 mitochondrial haplotypes reported by Swei *et al*. (2003, pp. 505–506) remaining evident.

Wilder *et al.* (2020, unpaginated) also tracked genetic diversity and fitness (measured by reproductive success) within a captive population of PPM founded from individuals collected from the three extant populations. They observed an increase in fitness of admixed individuals in the F1 and F2 generations relative to the founding populations, suggesting the possibility that the founding populations suffer from inbreeding depression (decreased fitness from interbreeding closely related individuals). However, the potential for simultaneous introduction of outbreeding depression (decreased fitness from interbreeding distantly related individuals) from admixture could not be ruled out, as fitness waned in subsequent generations. Thus, additional study is needed to understand the genetic underpinnings of the fitness patterns observed in the captive population. Yet, across six generations of interbreeding, Wilder *et al.* (2020, unpaginated) found a strong negative correlation between individual reproductive success and Dana Point ancestry, which is consistent with a high deleterious genetic load (presence of unfavorable genes in a population) in this population, and suggests that a genetic management strategy that proposes to restore gene flow among the populations should be unidirectional for Dana Point.

To understand the potential for introducing outbreeding depression from restoration of gene flow among the extant populations, King *et al.* (2018, p. 25) conducted karyotype analysis to study whether there are inter- or intra-population chromosomal differences among or within the PPM populations. Preliminary results suggest that the diploid chromosome number in PPM varies, and ranges from 56 to 58, with three identified cytotypes (King *et al.* 2018, p. 25). However, it remains uncertain whether there are fixed chromosomal differences among populations due to small sample size of the karyotype analysis, karyotype variation found within individuals and populations, and the potential for cultural artifacts from poor cell growth in culture (the analysis uses tissue cultured post-mortem) (King *et al*. 2018, p. 25).

A genetic management plan for the subspecies is currently in preparation (Miller 2019, *in litt.*).

Captive Propagation

Because no new PPM populations had been discovered since 1995, and there was difficulty finding enough animals sufficient to support a translocation, in 2011 the decision was reached to establish a PPM captive breeding program as a source of animals to create additional populations called for in the PPM Recovery Plan (USFWS 1998, p. 35). The objectives of the captive breeding program are to: "1) obtain a representative sample of the genetic variation of the subspecies currently present in the wild; 2) establish a demographically stable captive population that is able to sustain the harvest of animals for release; and 3) retain genetic diversity in the captive and release populations until reintroduction is complete" (Miller and Shier 2011, p. 1).

The SDZ-ICR obtained grant funding and established the captive breeding program in 2012. The initial strategy set forth in the genetic management plan for the captive population (Miller and Shier 2011) was to collect 10 individuals from each of the extant populations as founders for the

captive population. Due to the need to phase PPM collections and to maintain genetic variation in the captive population, between 2012 and 2019 a total of 39 individuals have been collected as founders for the captive population, including 11, 14, and 14 individuals (respectively) from the Dana Point, South San Mateo, and Santa Margarita populations. Breeding of mice in the captive facility has been successful, with over 300 mice produced to date, including 156 mice released at LCWP between 2016 and 2019.

In addition to providing individuals for reintroduction, the captive breeding program has studied PPM genetics, reproduction, behavior, and diet.

Reintroduction Efforts

Reintroductions of PPM into previously unoccupied habitat were initiated in 2016 at LCWP in Orange County, with the release of 50 PPM from the captive breeding facility at the Water Tank 1 site (King *et al.* 2018, p. 14). Following this release, there was no apparent over-winter survivorship, prompting a supplementary release of 49 mice at Water Tank 1 in 2017 (King *et al.* 2018, p. 18; Shier and King 2018, pp. 22, 39). These animals successfully bred following their release (39 young of the year documented), and a combination of released and wild born individuals survived overwinter. Following the detection of 37 mice at Water Tank 1 in April of 2018, a predator exclusion fence surrounding this site was removed and re-installed 100-yards to the south around a second release site, Water Tank 2.

In May of 2018, a cohort of 28 captively born PPM were released at Water Tank 2. During post-release monitoring performed at both sites in August of 2018, just 4 individuals were confirmed to remain at Water Tank 1, and 17 PPM were found at Water Tank 2, 1 of which was a wild born female. Following the wet winter of 2018–2019, post-release monitoring was unable to detect any PPM remaining at Water Tank 1, and just one PPM was confirmed to survive over winter at Water Tank 2.

In May of 2019, a supplementary release of 29 captively bred PPM was performed at Water Tank 2. By August of 2019, 10 PPM were confirmed to persist at Water Tank 2, but there was no evidence of successful reproduction within this release cohort.

In summary, these reintroduction efforts have documented successful reproduction of released animals, and both captive and wild born PPM have survived overwinter. However, rates of reproduction and survivorship both must be appreciably improved to establish a viable, self-sustaining population. During 2020, another population augmentation at LCWP is proposed to be implemented, using an experimental design to study if pre-release familiarization with heterospecific competitors can improve release outcomes (Shier and Swaisgood 2020, entire).

Another effort to improve reintroduction outcomes has been to develop a systematic and repeatable process to guide the selection of additional receiver sites for PPM reintroductions (Chock and Shier 2020, entire). This process uses field data and expert input to rank sites based on a list of variables related to their strengths, weaknesses, opportunities and threats (White *et al.* 2015, entire). In 2019, this process was used to rank four potential receiver sites (El Segundo Dunes, Alta Vicente,

Laguna Coast, and Tijuana Estuary) (Chock and Shier 2020, entire). In 2020, three additional sites are proposed to be evaluated using this process.

THREATS ANALYSIS

FACTOR A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

At listing in 1994, project construction was a threat to PPM due to the imminent loss of habitat on Dana Point Headlands. Then in the 2010 5-year review, we discussed six threats to PPM under Factor A: 1) project construction, 2) military training activities, 3) fire management practices, 4) fire breaks and fuel breaks, 5) road and utility maintenance, and 6) recreation activities and habitat disturbances. In this threats analysis, we briefly summarize new information about those six threats discussed in 2010.

Project Construction

Since listing, PPM habitat has been impacted by four construction projects:

1. The Headlands Development and Conservation Plan which developed a residential and commercial development on 29 ha (71 ac) of the 48 ha (121 ac) Dana Point Headlands property. As part of the overall development plan, 11.9 hectares (29.4 acres) of this property was left undeveloped (with the exception of a public access trail) and is permanently conserved and managed by CNLM as the Dana Point Preserve for the benefit of sensitive species and the public.

2. Construction of the Crucible Challenge Course, which involved the loss of 3.2 ha (8 ac) of occupied or suitable PPM habitat within Oscar One.

3. Realignment and installation of pipelines and facility upgrades associated with the Basewide Water Infrastructure (BWI) project, which involved the temporary loss of 0.21 ha (0.52 ac) of occupied and suitable PPM habitat at South San Mateo.

4. The 51 Area Reservoir Repair Project, which includes repairing and restoring damage caused to facilities and the environment from the accidental release of water from Reservoir 51772 in April of 2012; replacing roofs on three reservoirs and replacing concrete surfacing within the reservoir facility; and repairing impacts to PPM habitat in the 51 Area of MCBCP from a number of grading and earth disturbing incidents. Cumulatively, impacts from this project are estimated to impact 0.72 ha (1.79 ac) of PPM habitat, including the permanent loss of 0.17 ha (0.43 ac) of habitat. Our Biological Opinion on the project (USFWS 2017, pp. 7–11) included measures to compensate for temporary and permanent impacts to PPM, through habitat restoration and enhancement. MCBCP reinitiated consolation in 2018, and our subsequent Biological Opinion (USFWS 2019, pp. 9–13) included additional conservation measures to avoid and minimize project impacts.

We discussed the first two projects in the 2010 5-year review (refer to USFWS 2010, pp. 44–45) and have since formally consulted with the U.S. Marine Corps on the impact of the latter two projects on PPM. Construction of the BWI project has already been implemented, while construction of the 51 Area Reservoir Repair project is anticipated to commence in 2020 or 2021. We determined that these projects would not jeopardize the survival and recovery of PPM.

While direct land use conversion is not currently a threat to extant PPM populations, further impacts to the remaining suitable habitat within the subspecies range could affect recovery by removing potential reintroduction sites. Activities in PPM habitat other than project construction—such as military training, road grading, and utility maintenance—are discussed separately below.

Military Training Activities

In 2010, we determined that military training activity at San Mateo South likely impacted few PPM (USFWS 2010, p. 45); training activity is not impacting PPM at San Mateo South at this time.

In 2006, expanded training activities within the Oscar One training area at Santa Margarita impacted PPM habitat through vegetation removal, addition of new training elements, soil compaction, and increased foot and off-road vehicle traffic (USFWS 2010, p. 46). Because PPM aestivate in shallow burrows, foot and vehicle traffic can also result in death or injury to PPM. Following the documentation of these expanded training activities, the Marine Corps modified the location of some of these training areas to locations where PPM had not been detected to minimize impacts to PPM (USMC 2007, *in litt*., cited in USFWS 2010, p. 46). Land navigation and other training practices continue to degrade PPM habitat south of Macs road, where PPM were once densely concentrated (Miller and Pavelka 2008, entire) and now are absent or only detectable in trace numbers (Brehme *et al.* 2018, pp. 20, 22, 40; Brehme *et al.* 2019, pp. 6, 17).

In 2012, about 0.61 ha (1.5 ac) of PPM-occupied habitat within Santa Margarita were disturbed due to the establishment of a temporary training/bivouac site. MCBCP moved the temporary training/bivouac site to an area without PPM and consulted with the Service to address potential impacts associated with restoration of the site. Restoration of the vegetation at the bivouac site was completed in 2019.

Fire Management Practices

PPM residing within habitat where there is a fire have potential to succumb to the fire from burning, asphyxiation or heat prostration, or may survive either by fleeing or by sheltering in place. Studies that have been performed to understand the potential for fire to result in direct harm to small mammals suggest many small mammals are able to shelter in place within crevices in rock outcroppings, burrows, and unburnt or protected areas within the burn perimeter that provide insulation from direct heat and fresh air (Howard *et al.* 1959, pp. 232–234; Tevis 1956, pp. 407–408; Gashwiler 1959, pp. 134–138; Lawrence 1966, pp. 284–287; Quinn 1979, pp. 131–132; Price *et al.* 1995; and others). Due to its burrowing habit, PPM in particular are likely to be predisposed to be able to survive and withstand fire by sheltering in place within burrows, where there is adequate insulation from heat.

Price *et al.* (1995, p. 55) found that fire in late spring had no effect on survival of another rodent species (Stephens' kangaroo rat). In fact, fire at this time of year likely opens up the habitat, creating areas of bare ground and promoting forb growth (Price *et al.* 1995, p. 57). It is likely that some PPM residing within habitat that burns succumb to the fire or flee from the burned habitat, and may be more at risk from loss of their burrows through increased risk of predation, increased competition with hetero- and conspecifics, and decreased reproduction.

In 2010, we discussed how habitat quality for PPM could be altered by fire. Studies of the recovery of small mammal communities following fire suggest that declines in the abundance and diversity of small mammals following fire are often temporary and tied to the dynamics of vegetation recovery (Diffendorfer *et al.* 2012, pp. 440, 447). Species in the family Heteromyiidae associated with open vegetation communities—such as *Dipodomys stephensi*, and some species in the genus *Perognathus* (including PPM)—have been documented to benefit from the opening of vegetation from fire (Price and Waser 1984, pp. 1165, 1167–1168; Bock *et al.* 2011, pp. 135–136; Diffendorfer *et al.* 2012, pp. 440–445; Brehme *et al.* 2018, pp. 18, 31, 44). Other taxa associated with more closed habitat (e.g., woodrats, *Peromyscus californicus*) are lost over the short term, and only recolonize burned areas once there is a return of sufficient shrub cover (Wirtz II 1981, p. 245; Diffendorfer *et al.* 2012, pp. 440–445).

If fire occurs too frequently or at the wrong time of year, displacement of native forbs and shrubs by the invasion of nonnative grasses and forbs can result in habitat type conversion (O'Leary and Westman 1988, p. 779; D'Antonio and Vitousek 1992, pp. 63–68; Minnich and Dezzani 1998, pp. 383–384; Keeley *et al.* 2005, pp. 2114–2125) resulting in a long term loss of habitat suitability for PPM from the accumulation of nonnative grasses and thatch.

At Dana Point, San Mateo South, and the formerly occupied San Mateo North site, a lack of recent fire (e.g., for several decades or more) has resulted in a mature coastal sage scrub canopy under which there is little bare ground or growth of annual forbs, due to shading and an accumulation of duff and woody debris. This appears to have led to a gradual decline in habitat suitability for PPM at these sites, because of the loss of habitat openings that are thought to be an important component of PPM's preferred microhabitat (Loda *et al.* 1999, p. 8; Spencer *et al.* 2000, pp. 12–15; Montgomery 2005, pp. 7–8), and suppression of annual forbs and grasses that are an important component of PPM diet.

In 2010, we discussed the use of prescribed fire within the Edson Range training area that overlaps a portion of the Santa Margarita population. Within Edson Range, there are several live firing ranges where use of munitions has potential to ignite fires that could spread outside of this training area into adjoining habitat. Thus, prescribed fires are ignited by the Marine Corps in Edson Range to manage fuel loads and reduce the potential for fire from spreading into adjoining portions of the base. In our 2010 analysis, we stated that the longer term impact of fire to PPM populations was unknown, with the potential for both positive and detrimental effects. However, a "mosaic burning strategy" could reduce the risk of catastrophic fires where larger areas would be type converted to less suitable habitat (i.e., shrubland to grassland) (Price *et al.* 1995, p. 60).

Since 2010, monitoring data provided new information about the relationship between fire and PPM habitat use within Edson Range (Brehme *et al.* 2018, entire). Direct evidence of the potential benefit to PPM from fire is suggested by monitoring that documented PPM colonizing newly burned habitat within Edson Range, following fires that burned a portion of the range in 2012 and 2014 (Brehme *et al.* 2018, p. 22). Further evidence of the potential benefit from fire to PPM is suggested by modeling of habitat use within Edson Range, where the primary predictor of local extinction across years is years since last fire, with a high probability of local extinction found after 6 years without a burn event (Brehme *et al.* 2018, p. 31). Combined, these results suggest that within Edson Range—where there has been a history of frequent prescribed fire, and the vegetation is dominated by nonnative annual grasses and forb species which accumulate thatch over time—PPM benefit from some intermittent level of burning that serves to open up the vegetation community and promote annual plant germination. Fire has been absent within most of Edson Range since 2012 and habitat use by PPM has declined within the Santa Margarita population since 2016. Based on these conditions, the MCBCP initiated consultation with the USFWS in 2019 on the use of prescribed fire within the Edson Range and Oscar One training areas for the dual purposes of fire risk reduction and PPM habitat enhancement.

Fire Breaks

The Marine Corps and California State Parks maintain fire breaks in the vicinity of San Mateo South and the historical San Mateo North population, respectively (USFWS 2010, p. 47). Fire breaks are maintained by disking or blading soil, which may crush PPM burrows and/or harm individuals through direct injury or displacement. Following the discovery of PPM at South San Mateo in 1995, the Marine Corps abandoned maintenance of some of the fire break segments, or portions thereof, in the vicinity of this population to minimize and avoid impacts to PPM, but fire breaks occupied by PPM are still occasionally disked or created by facilities maintenance staff on site (Stewart 2014, *in litt.* p. 1, Enclosure pp. 1–2; USFWS 2019, pp. 5, 27).

In 2012, about 0.13 ha (0.32 ac) of occupied PPM habitat was impacted within a former east-west trending ridgeline firebreak at San Mateo South. MCBCP restored this habitat for PPM (USFWS 2019, pp. 26, 32), and monitoring indicates this area was recolonized by PPM in 2017, approximately 5 years after the disking incident.

In 2014, PPM habitat was disked when a new fire break was created near Base housing off of Basilone Road at San Mateo South. This activity likely crushed burrows and harmed individual PPM residing within the footprint of the fire break (Stewart 2014, *in litt.*, p. 2). To monitor the response of PPM to this habitat disturbance, the MCBCP PPM monitoring program placed an "Impact" monitoring grid within the disked area that detected PPM in the cleared and adjoining area the following season (Brehme *et al.* 2017, pp. 5, 7, 35). Following recolonization of this area by PPM, this area was disked again in June of 2017 (Sullivan 2017, pers. comm., unpaginated; USFWS 2019, pp. 5, 27). However, continued monitoring of the impact grid indicates that this firebreak has again been recolonized by PPM following the second disking incident (Brehme *et al.* 2018, p. 18).

Prior to extirpation of the San Mateo North PPM population, State Parks would periodically spread plant mulch over the fire break adjoining this population to suppress new plant growth and reduce maintenance needs. This layer of mulch created moist soil conditions favoring the proliferation of invasive Argentine ants, which colonized the adjoining habitat and are believed to have contributed to degradation of habitat quality for PPM at this locale (Suarez *et al.* 1998, p. 2050; Brehme and Fisher 2009, p. 32).

In conclusion, PPM colonization of cleared habitat following creation of firebreaks, combined with firebreak maintenance practices at South San Mateo, is likely resulting in some ongoing incremental impacts to PPM habitat and direct harm to individual PPM on a periodic basis.

Road and Utility Maintenance

Dirt roads on MCBCP are maintained either by the base, or by utility companies [San Diego Gas and Electric (SDGE), Southern California Edison]. For routine road maintenance, SDGE follows practices to avoid and minimize the potential to injure or kill PPM. Therefore, it is likely that routine road maintenance results in few, if any, individual PPM injured or killed on an annual basis. San Diego Gas and Electric also coordinates with the Service to minimize or mitigate take during routine road and electric line maintenance.

During 2014, the Marine Corps started surfacing the dirt roads that intersect the distribution of the PPM population within the Oscar One training area with pea gravel and/or crushed stone. Based on alteration of the road surface from dirt to a composite rock substrate, and the observation of decreasing road permeability to movements of another pocket mouse across a change of road type from low-use dirt, low-use secondary paved, to rural 2-lane highway (Brehme *et al.* 2013, pp. 713, 715–716), it is possible that this road surfacing could contribute to the fragmentation of PPM habitat within the Santa Margarita population from road avoidance behavior.

In 2012, an emergency access road was created through PPM habitat while performing repairs in response to damage to drainage ditches from the accidental release of water from the San Onofre Reservoirs. This resulted in the grading of an estimated 0.34 ha (0.83 ac) of PPM habitat within the San Mateo South population, and likely resulted in the death or injury of at least seven PPM (Snyder 2012, *in litt.*, p. 2). Monitoring of the PPM population indicates that the emergency access roadbed was recolonized by PPM following this grading incident, but was subsequently disked in 2017 in association with the creation of an adjoining fire break (Brehme *et al.* 2018, p. 18) (refer to discussion in **Fire Breaks**). The Marine Corps has consulted to place a composite surface on this road and establish it as a permanent access road for maintenance of the San Onofre reservoir facilities (USFWS 2019, p. 2).

Recreation Activities and Habitat Disturbances

Prior to 2005, a variety of unauthorized habitat disturbances (dumping of garden waste, marijuana growing, homeless encampments) occurred at Dana Point (USFWS 2010, p. 49). These activities were curtailed after 2005 due to management of the site by CNLM. In December of 2009, the public was granted daytime access to a formal trail within the Dana Point Preserve. While the

trail has likely reduced the incidence of trespass, it has also led to an increase in human presence on the trail through the Dana Point Preserve during daytime hours (USFWS 2010, p. 49.

Dana Point and LCWP are both accessible to the public and used for passive recreational purposes. Though the public is prohibited from venturing off trail, there are instances of off trail recreation (such as hiking and mountain biking), as well as dogs off leash (Merrill and Rogers 2019, p. 23). Because San Mateo South falls entirely within a military installation, it receives the least impact from trail creation and public trespass. However, nearby base residents occasionally use the existing road network for mountain biking, hiking and dog walking.

In 2010, we concluded that recreation activities and habitat disturbances at the three northern PPM populations [Dana Point, San Mateo North (presumed extant at the time), and San Mateo South] caused low level, continual disturbance that resulted in the deposition of trash, creation of trails, loss of vegetation areas, and compacted soils. Currently, the effects of these recreational activities are likely low in overall magnitude, at least relative to other disturbances.

FACTOR B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

At listing, the large number of specimens collected for scientific purposes from the El Segundo area in 1931 and 1932 was cited as a potential factor contributing to the decline of the historical PPM population at that locale (59 FR 49761). However, in the final listing rule, we included no information to suggest that scientific over-collecting remained a threat to PPM. In the 2010 5-year review, we concluded that overutilization for any purpose did not appear to threaten PPM (USFWS 2010, p. 50). Similarly, overutilization does not appear to be a threat at this time.

FACTOR C: Disease or Predation

In the listing rule, we identified predation by red fox and feral/domestic cats as a threat to PPM (59 FR 49762). Then in the 2010 5-year review, we considered multiple predators—including domestic and feral cats—as threats to PPM, as camera surveys at Dana Point Headlands detected at least seven potential predators (USFWS 2010, p. 51, citing Carranza 2009, pers. comm.). In 2010, domestic pet activity was fairly heavy at San Mateo North, and at San Mateo South; Montgomery (SJM Biological Consultants 2003, p. 31) observed several cats entering occupied PPM habitat. At Dana Point Headlands, the predatory threat from cats was ameliorated to some extent by management of the Dana Point Preserve. However, overall, we considered predation from cats an ongoing threat to PPM at Dana Point Headlands, San Mateo South, and San Mateo North.

PPM mortality due to native fire ants has been observed three times since the mid-1990s. Mortality occurred when PPM confined in Sherman live-traps (placed for population monitoring) were attacked and killed by ants. An instance of mortality due to ants was first recorded during monitoring in 1995 or 1996, and also occurred in 2004 (Miller 2004, pers. comm., unpaginated) and 2014 (Brehme *et al.* 2018, p. 44). The invasive, nonnative Argentine ant is another ant species that is known to prey on hatchling birds and is present at each of the extant PPM populations. Brehme *et al.* (2018, p. 48) hypothesized that native fire and invasive Argentine ants may be predators of PPM that could be responsible for PPM population declines at some locations. Native fire ants are the more likely threat to the Santa Margarita population, and Argentine ants a potential threat

to the Dana Point and South San Mateo populations. To help determine the potential for these ant species to predate PPM underground, USGS performed a pilot study that involved placing dead infant ("pinky") mice in artificial burrows and tracking the amount of time and response of the ants to the mice upon discovery (Matsuda 2020, pers. comm., unpaginated). This study suggested that, of the two species, native fire ants are more likely to forage below ground and prey upon PPM when they are in their burrows (Matsuda 2020, pers. comm., unpaginated). However, the amount of natural PPM mortality from ants of either species (fire or Argentine) remains unknown.

In summary, predation remains a threat to PPM across the species range, but we do not have information about the amount of PPM mortality from either native or nonnative predators, including feral and domestic cats, fire ants, and Argentine ants. Therefore, the overall magnitude of this threat is unknown.

We did not identify threats from disease to PPM at listing or in the 2010 5-year review (USFWS 2010, pp. 51–52). To date, there is no evidence that disease or parasites are affecting PPM.

FACTOR D: Inadequacy of Existing Regulatory Mechanisms

At listing, we discussed five general regulatory mechanisms that could provide protection for PPM in the absence of the Act. Subsequent to listing, PPM was discovered on Marine Corps Base Camp Pendleton (MCBCP), so in the 2010 5-year review, we discussed two applicable Federal regulatory mechanisms: the National Environmental Policy Act and the Sikes Act Improvement Act.

Our 2010 discussion of regulatory mechanisms providing some protection for PPM is still accurate. We believe that the Act continues to remain the primary regulatory mechanism providing for the conservation of PPM through consultation on Federal lands. Refer to the 2010 5-year review (USFWS 2010, p. 52) for a complete discussion.

FACTOR E: Other Natural or Manmade Factors Affecting Its Continued Existence

Small population size

At listing, we considered PPM highly susceptible to extinction from environmental or demographic factors, due to the species' small population size and restricted range (59 FR 49762). We also discussed small population size in the 2010 5-year review, noting that ongoing and/or recent trapping efforts had detected no or relatively few PPM at the Dana Point Headlands, San Mateo North, and Oscar One (USFWS 2010, p. 59).

Small populations are more susceptible to inbreeding and to genetic, demographic, and environmental stochasticity (i.e., loss of genetic variation; high variability in age and sex ratios; and random, natural events such as drought, flood, or predation; respectively). Therefore, small populations have higher probabilities of extinction than larger populations.

Analysis of genetic samples collected during population monitoring suggest that effective population sizes within the extant populations are universally low and cause for concern. The

estimated effective population sizes at Dana Point, South San Mateo and Santa Margarita are (respectively) N_e=3.3 (95 percent C.I.=2.2-7.4), N_e= 25.0 (95 percent C.I.=15.7-47.1), and N_e=50.6 (95percent C.I.=43.1-60.0) (Wilder *et al.* 2020, unpaginated). These results suggest that all three populations are vulnerable to loss of genetic variation and adaptive potential over time, with the Dana Point and South San Mateo populations below the threshold at which reduced fitness from mating of closely related individuals is expected. Poor reproductive performance of Dana Point animals in captivity, and loss of Dana Point genetic representation within the captive colony over time, further suggests that this population is already suffering from reduced fitness relative to the other PPM populations (Wilder *et al.* 2020, unpaginated). Finally, a comparison of contemporary genetic variation with variation measured from tissue collected prior to 2003 indicates that all populations have suffered recent population declines and a significant loss of genetic variation, with the Dana Point population exhibiting the greatest and most concerning loss (Swei *et al.* 2003, pp. 511–512; Wilder *et al.* 2020, unpaginated).

By maintaining genetic diversity and increasing the number PPM populations, current captive breeding and reintroduction efforts may help to ameliorate the threat of small population size in the future. However, this threat is currently high in overall magnitude, and is exacerbated by other threats to PPM from habitat disturbance, fragmentation, and predators.

Habitat fragmentation

Our discussion of habitat fragmentation in the 2010 5-year remains accurate. Urbanization and land-use conversion have fragmented the historical range of PPM such that populations now operate as independent units, rather than as parts of a stable metapopulation. Habitat fragmentation reduces population resiliency by creating barriers to dispersal, and by increasing the vulnerability of remaining habitat to disturbance and invasion by nonnative species. Bolger *et al.* (1997, pp. 552–563) studied the effects of habitat fragmentation on rodents in southern California. They found that species with highly fragmented populations were more frequently extirpated from small habitat fragments. The quality of fragmented habitat may also decline as a result of edge effects, such as increased artificial night-time lighting, which may increase vulnerability to visually aided predators (Dice 1945, p. 393; Clarke 1983, p. 205), or result in direct habitat avoidance (Kotler 1984, p. 689; Price *et al.* 1984, pp. 354–355; Brown *et al.* 1988, p. 408). SDZ-ICR is currently studying the effects of artificial light on PPM.

Nonnative plant species

Nonnative grass species negatively affect PPM by altering habitat structure and food resources. Models of PPM occupancy by Brehme *et al.* (2018, p. 2) found that nonnative grass cover is negatively associated with PPM occupancy and colonization, and positively associated with extinction. Additionally, nonnative grass species can outcompete native forbs, which are strongly

correlated with probability of colonization (Brehme *et al.* 2018, p. 2). We believe that this threat is high in overall magnitude.

Climate change

Climate change was not mentioned as a threat to PPM at listing. In 2010, we recognized that climate change had the potential to affect listed species and their habitats, but we lacked information about projected changes, and the potential impacts to PPM were unclear.

Since 2010, scientists have used downscaled climate models to project changes in temperature, precipitation, humidity, snowpack, sea level rise, and wind speed for California under a range of future climate scenarios (see Pierce *et al.* 2018, entire; Kalansky *et al.* 2018, entire). Temperature has increased throughout Southern California over the past century, and warming is expected to continue (Hall *et al.* 2018, pp. 10–11). However, the ocean provides a buffering effect in coastal regions (including the extant populations of PPM), and these areas are projected to experience relatively lower amounts of warming compared to inland regions (Hall *et al.* 2018, p. 10, Figure 3). Precipitation in Southern California is highly variable (Hall *et al.* 2018, p. 12), and for the Los Angeles region, models project small mean changes compared to historical variability. In the future, wet and dry extremes are projected to increase (Hall *et al.* 2018, p. 13).

While models project increases in temperature, the effects of those changes to PPM are still uncertain. Likewise, the effects of increased wet and dry extremes to PPM individuals or habitat are unclear. PPM surveys by USGS documented increasing habitat occupancy on MCBCP during 5 years of drought: amount of occupied habitat increased from 190 ha (470 ac) in 2012, to 335 ha (828 ac) in 2016 (Brehme *et al.* 2018, p. 43). Then in 2017— where seasonal rainfall (431.3 mm [17.0 inches]) was 28 percent above the historical average (338 mm [13.3 inches])—Brehme *et al.* (2018, p. 43) reported a decline in occupancy to 208 ha (514 ac), which occurred primarily within the Edson Range portion of the Santa Margarita population. At the same time, vegetation at Edson changed from open, low-growing forb and grasses to taller forbs and grasses with little open ground (Brehme *et al.* 2018, p. 43). Occupancy modeling supported the hypothesis that higher vegetation cover—which reduced areas of open ground for PPM foraging and dust bathing—was the greatest predictor of localized extinction across all years and sites (p. 43), whereas the interaction between rain and soils data poorly predicted localized extinction. Increased wet and dry extremes, and the resulting increases or decreases in forb and grass cover, may increase the variability in inter-annual PPM occupancy in the future.

RECOVERY CRITERIA

Recovery plans provide guidance to the USFWS, States, and other partners and interested parties on ways to minimize threats to listed species, and on criteria that may be used to determine when recovery goals are achieved. There are many paths to accomplishing the recovery of a species and recovery may be achieved without fully meeting all recovery plan criteria. Overall, recovery and the assessment of a species' degree of recovery is a dynamic process requiring adaptive management, which may, or may not fully follow the guidance provided in a recovery plan. We focus our evaluation of PPM's status in this 5-year review on progress that has been made toward

recovery since the species was listed (and since the 2010 5-year review) by eliminating or reducing the threats discussed in the five-factor analysis. In that context, the extent to which threat factors have been reduced or eliminated indicate progress towards fulfilling recovery criteria. Criteria for downlisting are discussed below.

Downlisting Criterion 1: *Ten populations are independently viable and stable or increasing, and their habitats are secure (free of risk of loss) and fully protected through fee ownership by a resource agency or conservation program, conservation easement, or other means of permanent protection. Populations of Pacific pocket mice shall be considered viable if the appropriate analysis of measured population parameters indicate that each of the 10 populations has a 95 percent or greater chance of surviving for 100 years.*

Discussion: In 2010, there were four extant populations of PPM: Dana Point, San Mateo North, San Mateo South, and Santa Margarita. Between 1995 and 2009, targeted surveys for PPM within its historical range had not documented new populations (USFWS 2010, p. 63). Suitable PPM habitat at one population (Dana Point) was (and remains) protected by conservation easement, and habitat at a presumed extirpated population (San Mateo North) was reasonably secure. In 2010, we concluded that attainment of recovery criterion 1 would likely rely on the establishment of additional populations by means of translocation. Habitat modeling and site reconnaissance efforts had identified a number of prospective receiver sites for subspecies translocation (Spencer *et al.* 2001, pp. 7–14).

Since 2010, there has been no change in habitat conservation status for any of the PPM populations. However, the PPM population at San Mateo North is now presumed extirpated. Therefore, there are now three extant populations of PPM.

A captive breeding program was initiated in 2012, and attempts to reintroduce PPM to LCWP are ongoing. The Service continues to work cooperatively with land managers (CNLM and MCBCP) and other partners (SDZ and USGS) to monitor PPM populations and promote recovery of the subspecies.

Conclusion: Recovery criterion 1 has not been met, because:

1. There are currently 3 extant populations of PPM. Those 3 populations are Dana Point, Santa Margarita, and South San Mateo. The downlisting criterion calls for 10 populations.

2. Of the three extant populations, habitat at one is fully, permanently protected (Dana Point, where 11.9 ha (29.4 ac) is under conservation easement. Habitat at San Mateo North is reasonably secure, although PPM is presumed extirpated from that location.

3. Viability of the three extant populations—such that populations have a 95 percent chance of surviving for 100 years—has not been assessed through a Population Viability Analysis.

Downlisting Criterion 2: *Occupied habitat consists of a minimum of 2,000 hectares (4,940 acres) that are secure and fully protected through fee ownership by a resource agency or conservation program, conservation easement, or other means of permanent protection.*

Discussion: Changes in animal densities, and the resources on which they rely (e.g., cover, seed resources), can influence the spatial distribution of animals. PPM population may fluctuate dramatically, and populations frequently appear to persist at low densities. Therefore, "area of occupancy" is dynamic rather than static. However, track tube monitoring at Dana Point and MCBCP can be used to estimate habitat occupancy from year to year.

At the time of our 2010 5-year review, surveys had not detected any PPM at San Mateo North (Brehme and Fisher 2009, p. 19), and a large portion of the Santa Margarita population had experienced a substantial decline (the Lower Mesa portion of Oscar One) (Spencer 2007, pp. B-50–B-52; Shier 2008a, p. 12; Shier 2008b, pp. 15–20). It is not clear if the decline in PPM occupancy suggested by those surveys was temporary or permanent (USFWS 2010, pp. 65–66). Based on minimum convex polygons (MCP) that circumscribed all historical capture locations at the four then-extant populations (i.e., including San Mateo North), the cumulative area of PPM "occupancy" was estimated to cover 793 ha (1,959 ac). However, this was likely an overestimate, since it was based on the compilation of capture locations over multiple years, and included developed areas and unsuitable habitat within MCBCP boundaries.

Between 2012 and 2019 at MCBCP, the highest PPM occupancy estimate was in 2016, when 335 ha (828 ac) were cumulatively estimated to be occupied by PPM across the Santa Margarita and San Mateo South populations (Brehme *et al.* 2019, p. 13). Occupancy estimates from 2019 at Camp Pendleton showed a decrease in estimated occupied habitat from 2016, to 118 ha (292 ac) (Brehme *et al.* 2019, p. 13). Similarly, the amount of occupied habitat at Dana Point declined to just 1.05 hectares in 2019 (Merrill 2020, entire).

Conclusion: Recovery criterion 2 has not been met, because:

1. Rangewide estimates are below 2,000 hectares. In 2019, a total of 118 ha (292 ac) were estimated to be occupied at the two extant populations on MCBCP and just 1.05 ha (2.59 ac) were estimated to be occupied at Dana Point.

2. A total of 11.9 ha (29.4 ac) of habitat at Dana Point Headlands is secure and fully protected.

Reintroduction efforts to expand the amount of occupied PPM habitat are underway at LCWP. Additionally, habitat enhancement efforts are ongoing at Dana Point. MCBCP is consulting with the Service on fire management in Edson Range, and MCBCP has recently developed a PPM management plan. If implemented, those management activities could increase the use of available habitat by PPM at Dana Point, Santa Margarita and South San Mateo.

Downlisting Criterion 3: *All Pacific Pocket Mouse populations are managed through a program to maintain genetic diversity for future generations.*

Discussion: In the 2010 5-year review, we discussed Swei *et al.* (2003, pp. 501–514), who estimated gene flow between Dana Point and MCBCP PPM populations, and reported that Dana Point had been relatively isolated from MCBCP for some time. We concluded that additional genetic study was needed to characterize genetic variation within and among populations, and to identify suitable methods for maintaining genetic diversity.

In 2011, Service and SDZ-ICR staff completed a genetic management plan for management of genetic variation within the captive and reintroduced populations of PPM (Miller and Shier 2011, entire). Establishment of the captive breeding program in 2012 has facilitated additional study of genetic variation within the extant PPM populations, and allowed close study of breeding outcomes from six generations of inter-population pairings in captivity (Wilder *et al.* 2020, unpaginated). Information gained from this research suggests that the Dana Point population is suffering from an accumulation of unfavorable genes within the population. The new genetic information is being used to draft a genetic management plan for the subspecies as a whole.

Conclusion: Recovery criterion 3 has not yet been met, but partners have made considerable progress to meet this criterion since 2010. SDZ-ICR has established a captive breeding program for PPM, and monitors and maintains genetic diversity in the captive population (see Miller and Shier 2011, entire; King *et al.* 2018, entire). Using information gained on the captive population, a genetic management plan for PPM is currently being developed for the subspecies by SDZ and USFWS, with input from other partners.

Downlisting Criterion 4: *All Pacific Pocket Mouse populations and essential habitat are managed so that current and potential threats (e.g., predation and disease) are eliminated or minimized to the extent that each population is not at risk of extirpation. Essential habitat is defined to mean that habitat necessary for the full recovery of the subspecies.*

Discussion: Efforts to expand available habitat for PPM have been implemented at Dana Point Headlands and San Mateo North.

At Dana Point, the "Habitat Management and Monitoring Plan for Dana Point Headlands Biological Open Space" (HMMP; URS and CNLM 2005, entire) was adopted in April of 2005. The goal of the management plan is to ensure long-term maintenance of ecologically sustainable conservation areas (URS and CNLM 2005, p. 21). CNLM conducted nonnative plant removal and habitat enhancement efforts, and also established a motion-activated camera trapping program to monitor potential predators of PPM within the preserve. In 2017 and 2018, CNLM continued trail maintenance activities, removed invasive plant species, and selectively thinned dead perennial vegetation (Merrill and Rogers 2019, p. 1). In 2020, USGS (in collaboration with CNLM and the City of Dana Point) is conducting vegetation thinning and woody debris removal, supplementing CNLM track tube surveys efforts, and performing occupancy modeling and abundance estimation, among other tasks (USFWS and USGS 2019, p. 2).

Although the San Mateo North PPM population falls within MCBCP, the area where PPM were distributed is leased and managed by California State Parks as part of San Onofre State Beach. State Parks occasionally patrols the area where PPM were distributed, and has erected fencing to constrain public access to a single trail in this vicinity (USFWS 2000, pp. 1–21; USFWS 2010, pp. 1–34). To enhance habitat and expand PPM distribution at San Mateo North, in 2001 MCBCP and State Parks implemented a 1.4 ha (3.4 ac) prescribed burn in an area adjacent to occupied PPM habitat (USFWS 2000, pp. 1–21). However, subsequent trapping has not reported expansion of PPM habitat use into the burned area (Montgomery 2005, p. 25; Brehme and Fisher 2009, p. 19). During the winter of 2010 the Service also funded State Parks to perform 4 ha (10 ac) of vegetation thinning at San Mateo North in an effort to enhance habitat for PPM (USFWS 2010, pp. 1–34). Despite these attempts to improve habitat quality, surveys have not detected PPM at San Mateo North since 2003.

In association with the biological opinion addressing operation of the Crucible Challenge Course, the Marine Corps committed to develop an adaptive management plan to maintain the PPM population within the Oscar One training area over the long term (USFWS 1996, p. 5). Since 2010, MCBCP funded USGS to monitor all of the PPM populations on Base, including San Mateo North, and to conduct discovery surveys in potential habitat elsewhere on Camp Pendleton. In December of 2019, the Marine Corps completed a PPM Management Plan that "presents discrete management actions intended to protect, conserve, and enhance PPM populations and habitat aboard MCBCP" (MCBCP 2019, p. 1). This plan acknowledges that specific enhancement actions not addressed within the plan (e.g., prescribed fire, vegetation management, translocation) may require consultation with the Service prior to implementation (MCBCP 2019, p. 2). It is anticipated that the Marine Corps will begin implementing the management plan for PPM in 2020.

Conclusion: Recovery criterion 4 has not been met. All populations are managed, but there are ongoing threats at all populations that continue to impact the subspecies' and the habitat where it occurs.

Table 1. Recovery criteria summary table

Criteria number	Criteria metric	2010	2020	Change between 2010 and 2020
1	10 populations extant	4 (counting San Mateo North, which was suspected to be extirpated)	3 (San Mateo North, presumed extirpated)	Additional data supports presumption that San Mateo North has become extirpated
1	10 populations fully secure	2 (Dana Point; San Mateo North considered reasonably secure)	1 (Dana Point; San Mateo North considered reasonably secure, but extirpated)	PPM presumed extirpated at one reasonably secure location
1	Populations independently viable (≥95% chance of surviving for 100 years)	Unknown	Unknown	Unknown
2	2,000 ha fully protected, occupied habitat	11.9 ha fully protected, occupied habitat (Dana Point)	11.9 ha fully protected, occupied habitat (Dana Point)	No change
3	Populations managed to maintain genetic diversity	Some study of PPM genetics had been completed but no comprehensive genetic management strategy had been identified	Genetic management plan for captive PPM completed (2011), recent findings from study of extant and captive population genetics being used to craft comprehensive plan	Improving
4	Threats to populations and essential habitat are eliminated or minimized	Threats to populations and habitat present at all sites (see text)	Threats to populations and habitat present at all sites (see text)	Some within site-change; refer to text

SYNTHESIS

PPM is currently extant at three fragmented populations, which are impacted by small population size and other threats discussed under Factors A, C, and E. The fragmented, relatively small populations are vulnerable to demographic, genetic, and environmental stochasticity (random fluctuations in sex ratios; loss of alleles or shifts in allele frequencies; and random, natural events impacting populations, respectively), and genetic study reveals that all of the PPM populations are vulnerable to continued loss of genetic variation over time. Loss of genetic variation decreases the capacity of PPM to adapt to changing environmental conditions in the future, and to withstand

population-level disturbances from human activities (military training activities, construction and maintenance activities, etc.), predators, or nonnative species.

Since 2010, the establishment of a captive breeding program by SDZ-ICR has provided individuals for reintroduction efforts, and has conducted basic research into PPM diet, behavior and reproduction. New genetic research has provided information about population fitness and current levels of genetic diversity, and will inform the genetic management plan for the subspecies. Multi-year monitoring efforts at MCBCP have provided important information about PPM population status and environmental variables important for PPM habitat suitability. However, one PPM population that was possibly extirpated in 2010 is now presumed extirpated (San Mateo North), threats are ongoing at all populations, effective population sizes are very low, and genetic diversity has declined within all of the PPM populations since 2002, indicating that all of the populations have experienced recent population declines.

In this review, we considered threats to PPM under the same five factors considered at listing. Based on the best scientific and commercial data, as summarized in this 5-year review and discussed in detail in the Species Biological Report, we find that PPM is still in danger of extinction throughout its range, and therefore meets the definition of an endangered species. We recommend no change in listing status.

RESULTS

Recommended Classification:

☐ **Downlist to Threatened**

☐ **Uplist to Endangered**

☐ **Delist** (*Indicate reasons for delisting per 50 CFR 424.11):*

- ☐ *Extinction*
- ☐ *Recovery*
- ☐ *Original data for classification in error*

☒ **No change is needed**

New Recovery Priority Number and Brief Rationale: No change (6C)

RECOMMENDATIONS FOR ACTIONS OVER THE NEXT 5 YEARS

1. Improve the status of Pacific pocket mouse on MCBCP by incorporating measures into the recently completed PPM Management Plan to avoid and minimize impacts to reduce military training impacts to the Santa Margarita population, and enhance habitat at South San Mateo and Santa Margarita.

2. Improve the status of PPM at Dana Point by implementing the Dana Point monitoring and habitat enhancement plan, and working with CNLM to revise and update the habitat monitoring and management plan for the Dana Point Preserve.

3. Finalize a PPM genetic management plan and implement strategies to maintain and increase genetic variation within the extant, captive, and reintroduced populations, with a particular focus to improve the genetic health of the Dana Point population over the near term.

4. Continue the PPM captive breeding program to provide a source of animals for reintroductions.

5. Continue efforts to create additional wild PPM populations from the captive population by: a) continuing with the reintroduction effort at LCWP; b) refining and adding to the prioritized list of reintroduction sites within the species historical range; and c) securing landowner permissions and authorizations to proceed with reintroductions at the top ranked sites.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW

Pacific pocket mouse
(*Perognathus longimembris pacificus*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

☐ Downlist to Threatened

☐ Uplist to Endangered

☐ Delist (Indicate reasons for delisting per 50 CFR 424.11):

☐ Extinction

☐ Recovery

☐ Original data for classification in error

☒ No change needed

New Recovery Priority Number and Brief Rationale: No Change (6C)

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

☒ Approve

SCOTT SOBIECH Digitally signed by SCOTT SOBIECH
Date: 2020.08.31 15:42:50 -07'00'

Scott A. Sobiech
Field Supervisor