Ben Lomond Wallflower (*Erysimum teretifolium*)

5-Year Review:
Evaluation and Summary

Photo: Jodi McGraw

U.S. Fish and Wildlife Service
Ventura Fish and Wildlife Office
Ventura, California

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5-YEAR REVIEW
Ben Lomond Wallflower (*Erysimum teretifolium*)

GENERAL INFORMATION

Species: *Erysimum teretifolium*
FR citation: 59 FR 5499
Date listed: 4 February 1994
Classification: Endangered

BACKGROUND

Most recent status review

U.S. Fish and Wildlife Service. 2008. Ben Lomond Wallflower (*Erysimum teretifolium*) 5-Year Review: Summary and Evaluation. Ventura Field Office. Ventura, California.

FR Notice citation announcing this status review

Endangered and Threatened Wildlife and Plants; Initiation of 5-Year Status Reviews of 76 species in California and Nevada. (86 FR 27462), May 20, 2021.

Critical Habitat Designation

No critical habitat has been designated.

State Listing

Listed as endangered under the California Endangered Species Act in 1981 (CNDDB 2022, data).

ASSESSMENT

Information acquired since the last status review

This 5-year review was conducted by the U.S. Fish and Wildlife Service (Service) Ventura Fish and Wildlife Office. Initiation of this review was announced through a Federal Register notice on May 20, 2021. We contacted land managers and species experts to request any data or information we should consider in our review, conducted a literature search, and reviewed information from habitat conservation plans, biological opinions, and permit reporting.

Background

Habitat and Distribution
Ben Lomond wallflower (*Erysimum teretifolium*) occurs within the sandhills of the Santa Cruz Mountains. The central range of the species is generally bounded by the communities of Ben Lomond, Glenwood, Scotts Valley, and Felton in Santa Cruz County (Figure 1). An outlying population is found at Bonney Doon Ecological Reserve approximately 5 miles west of the central concentration of occurrences. Typical Ben Lomond wallflower habitat is characterized by sandy soil and bare ground in areas lacking competition and shading from shrubs, trees, leaf

litter, or dense cover of competing forbs and grasses. Ben Lomond wallflower is adapted to tolerate moderate levels of disturbance that inhibit woody vegetation growth but allow it to complete its life cycle, which typically requires two to three years (biennial). The distribution of Ben Lomond wallflower is island-like because suitable habitat is interrupted by areas of unsuitable soils and vegetation, as well as development. The resulting populations are potentially genetically isolated from one another depending on the distance pollinators may travel.

Within the sandhills, Ben Lomond wallflower occurs at greatest frequency and abundance within the sand parkland and sand chaparral vegetation communities (McGraw 2019, pp. 7-8). Sand parkland is characterized by a sparse tree canopy (less than 50 percent cover) of ponderosa pine (*Pinus ponderosa*) and coast live oak (*Quercus agrifolia*) and low cover of chaparral shrubs (less than 25 percent). Sand parkland has an herbaceous understory of native and exotic annual forbs and grasses. Often, the understory is dominated by exotic species including rat-tail fescue (*Festuca myuros*), rip-gut brome (*Bromus diandrus*), rattlesnake grass (*Briza maxima*), smooth cat's ears (*Hypochaeris glabra*), and sheep sorrel (*Rumex acetosella*). Native species characteristic of the sand parkland understory include pussypaws (*Calyptridium monospermum*), golden aster (*Heterotheca sessiliflora*), yarrow (*Achillea millefolium*), and bracken fern (*Pteridium aquilinum*).

Sand chaparral is characterized by the presence of chaparral shrubs such as silverleaf manzanita (*Arctostaphylos silvicola*), chamise (*Adenostoma fasciculatum*), mock heather (*Ericameria ericoides*), sticky monkeyflower (*Diplacus aurantiacus*), buck brush (*Ceanothus cuneatus*), black sage (*Salvia mellifera*), and golden yarrow (*Eriophyllum confertiflorum*). Trees, such as knobcone pine (*Pinus attenuata*), may be present but with low cover (less than 20 percent) (McGraw 2019, pp. 7, 15-19). In sand chaparral, Ben Lomond wallflower occurs within gaps between these species in areas that are not shaded by shrubs. As density of chaparral shrubs increase, habitat suitability for Ben Lomond wallflower decreases.

Life History and Reproduction

Ben Lomond wallflower is a monocarpic biennial plant that produces leaves but not flowers in the first year after germination. Flowers are typically produced in the second year (less frequently 3 years and rarely 4 years after germination) and die after seed set. Rarely will plants flower in the first year following germination or survive to flower and set seed more than once. In a recent experimental introduction study, approximately 11 percent of seedlings survived to produce an inflorescence in the second year (McGraw et al. 2020, p. 41). Herbivory pressure is high on both vegetative and flowering individuals, reducing the number of plants that set seed (McGraw and Chrislock 2019a, p. 15). Germination and survivorship have been observed to follow annual rainfall patterns, with wetter years having greater germination and survivorship than drought years (McGraw and Jordan 2021, pp. 19-20).

Ben Lomond wallflower is largely self-incompatible, needing pollen from flowers not on the same plant in order to produce seed (Melen et al. 2016, p. 1983). Self-pollination sometimes results in fruit development, but the number of seed produced averages 6.5 times less than the amount of seed produced from cross pollination (Melen et al. 2016, p. 1983). Cross pollination between populations produces slightly more seed per fruit than cross pollination within population, suggesting that the small populations may be experiencing inbreeding depression

(Melen et al. 2016, p. 1983). Bees, butterflies, and beetles are the most commonly observed floral visitors (Melen et al. 2016, p. 1982-1983). Pollen limitation was evaluated as a potential source of population declines, but manually adding pollen to flowers did not increase seed set, suggesting that populations of Ben Lomond wallflower are not pollen limited (Parker et al. 2011, p. 1; Melen et al. 2016, pp. 1980, 1983).

Genetics

In 2020, a study evaluated a subset of Ben Lomond wallflower populations to test predictions about the distribution of genetic diversity in a highly fragmented species that is also an outcrossing obligate (Valle et al. 2020, entire). Valle *et al.* (2020, p. 13) found that the majority of genetic diversity was found within populations, rather than among populations, suggesting that the mating system was the driving factor in determining the distribution of genetic diversity. The remaining genetic diversity could be explained by an abundant center model, where populations become increasingly differentiated from a central cluster of populations as distance increases (Valle et al. 2020, p. 18). The study also found evidence that individuals from Quail Hollow Ranch Park had been introduced to Bonny Doon Ecological Reserve, potentially in an attempt to rescue the declining population at Bonny Doon Ecological Reserve (Valle et al. 2020, pp. 13, 15). Valle *et al.* (p. 19) concluded that a majority of the genetic diversity found within Ben Lomond wallflower populations could be preserved within a single population, but some unique genetic information was isolated within peripheral populations and thus should be considered a conservation priority to retain all observed genetic diversity within the species. Additional research is needed to further understand which populations have the highest conservation value for preserving a majority of, as well as unique, genetic diversity because only a subset of populations were evaluated.

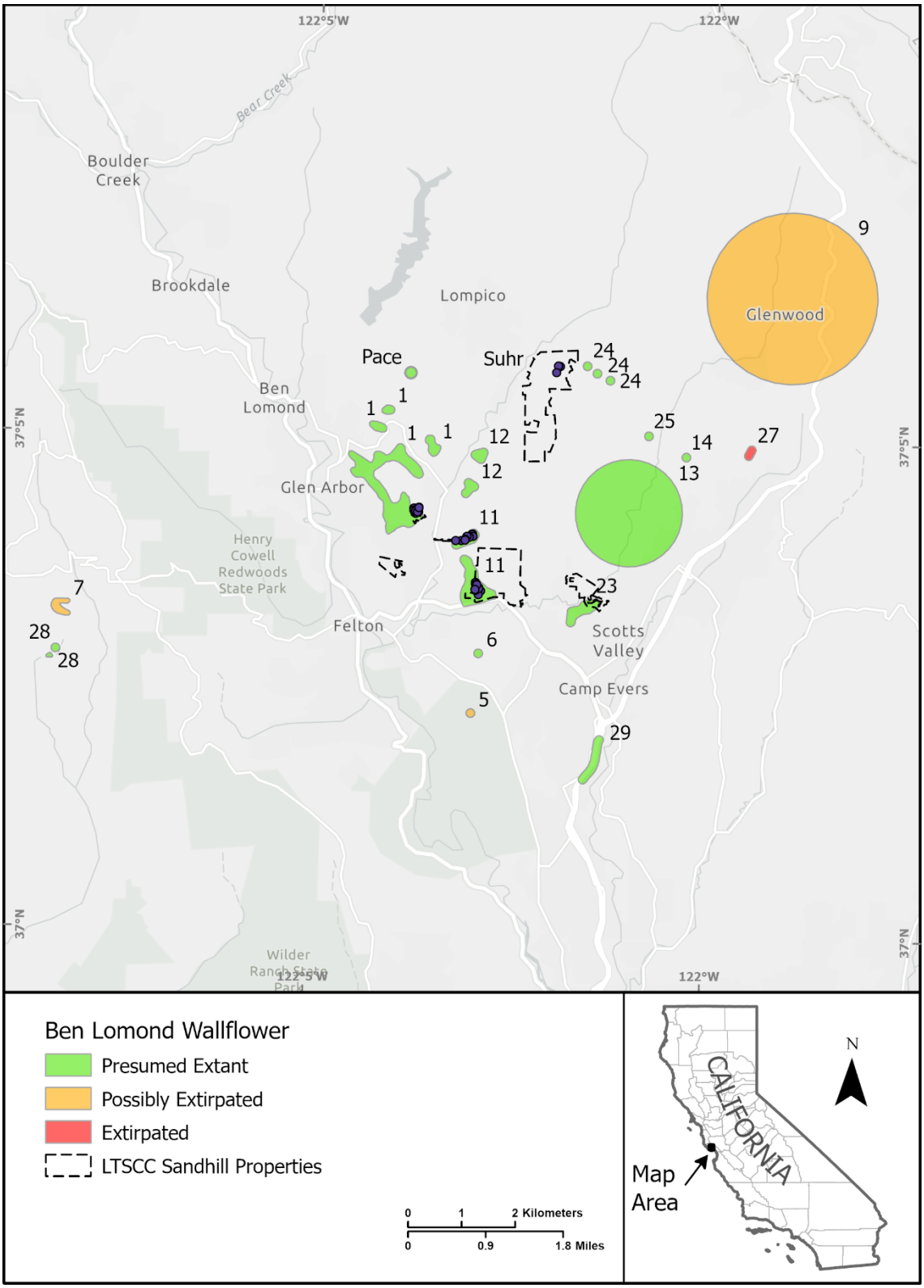

Figure 1. Ben Lomond wallflower (*Erysimum teretifolium*) California Natural Diversity Database (CNDDB) occurrences and Land Trust of Santa Cruz County (LTSCC) property and point data (CNDDB 2022, data; McGraw 2019, data). Element occurrence numbers are labeled where available.

Abundance and Population Trends

Population abundance data are only available for Quail Hollow Quarry Conservation Areas, Zayante Sandhills Conservation Bank, Bonny Doon Ecological Reserve, and Quail Hollow Ranch Park. The remaining locations have no information on abundance and population trends, or have infrequent single year data (Table 1). Data from Quail Hollow Ecological Reserve (also known as Quail Hollow Ranch County Park) between 2012 and 2022 suggest that the population is stable, with reproductive adults ranging between 200 and 400 plants (T. Kasteen 2022, pers. com.). The abundance of adult plants is measured as density and frequency at the Quail Hollow Quarry Conservation Areas and has remained relatively stable, but low, ranging between 1 and 6 plants within 20-meter squared plots between 2006 and 2020 (McGraw and Jordan 2021, p. 42). The number of plants within the Zayante Sandhills Conservation Bank has been historically low because that location captures only a small portion of a larger population that occurs within the Quail Hollow Quarry Conservation Areas. There was only a single adult plant observed in 2015 when annual monitoring began. However, through management and experimental outplanting the number of adult plants increased to 10 in 2021 (McGraw and Chrislock 2021, p. 27). The plants at the Zayante Sandhills Conservation Bank are best viewed as a small portion of a larger population that is increasing due to management efforts. The naturally occurring population at Bonny Doon Ecological Reserve has declined to six naturally occurring adult plants in 2022 (Kasteen 2022, pers. com.). The population has ranged between 1 and 50 adult plants since annual data began being collected in 2005. Experimental reintroductions have also taken place at this location with 837 adult plants observed in reintroduction areas in 2021 but declining to 189 plants in 2022 (Kasteen 2022, pers. com.). Herbivory, invasive species, litter, and drought have been attributed to the decline of the natural population and threaten the persistence of the reintroduction effort (Kasteen 2022, pers. com).

Ben Lomond wallflower populations are being managed on several Land Trust of Santa Cruz properties with abundance estimates from 2018 ranging from less than ten to approximately 100 adult individuals (McGraw 2019, data). No evaluation of trend can be made from the single year data.

Several other populations are possibly extirpated because no individuals were observed the last time data were recorded (Service 2008, pp. 6-8). These locations are unmanaged, and herbivory, increases in woody cover, invasive species, litter, and drought have contributed to the decline of the species. The remaining populations lack data from which to make an assessment. However, because they are on private land and subject to the same threats as managed populations, it is likely that they have experienced similar declines in abundance.

Recent evaluations of the seed bank at Bonny Doon Ecological Reserve suggest that there is little to no seed that remains ungerminated year to year (Parker et al. 2011, pp. 9-11; McGraw et al. 2020, p. 56). Therefore, the seed bank is unlikely to rescue the declining population at this location. These results from Bonny Doon Ecological Reserve are not representative of all populations; however, they may indicate that populations with similar declines in numbers of reproducing plants also have depleted, or decreasing, seed banks.

Table 1. Ben Lomond wallflower (*Erysimum teretifolium*) California Natural Diversity Database (CNDDB) occurrence number, location name, most recent adult abundance information, population trend assessment, and management notes. There may be more than one location with the same CNDDB occurrence number because the CNDDB groups all locations within 0.25 mile of each other even as ownership and management of distinct parcel may be different.

CNDDB Occurrence #	Name	Most Recent Adult Abundance Estimate (Year)	Population Status	Management
1	Qual Hollow Ranch Park	338 (2022)	stable[1]	monitoring
1	Quail Hollow Quarry	1-6 plants/20m^2 (2020)	stable[2]	habitat conservation plan, management and monitoring
1	Zayante Sandhills Conservation Bank	35 (2022)	low number, increasing[3]	management and monitoring
1	Bias Preserve (Land Trust of Santa Cruz County)	100-200 (2018)	unknown	management plan
5	Henry Cowell Redwoods State Park	0 (2003)	possibly extirpated	none
6	Hanson Quarry West Perimeter Set Aside	10 (2020)	low abundance	conservation easement, management and monitoring
7	Bonny Doon Ecological Reserve	0 (2022 natural); 106 (2022 experimental)	possibly extirpated, reintroduction declined from 2021[1]	historically vandalized and not restored, habitat present; experimental reintroduction
9	Private	na	possibly extirpated	none
11	Olympia Quarry	present (2022)	unknown	habitat restoration
11	Freeman Conservation Easement	4 (2020)	unknown	management and monitoring
11	Mayer Preserve	6 (2020)	unknown	management and monitoring

CNDDB Occurrence #	Name	Most Recent Adult Abundance Estimate (Year)	Population Status	Management
11	Morgan Preserve (Land Trust of Santa Cruz County)	100-200 (2018)	unknown	management plan
12	Private	77 (1986)	unknown	none
13	Private	0 (1986)	possibly extirpated	none
14	Private	10-20 (2022)	unknown	none
23	Bean Creek Preserve (Land Trust of Santa Cruz County)	<10 (2018)	unknown	management plan
24	Private	128 (1986)	unknown	none
25	Private	20 (2020)	unknown	none
27	Private	0 (2008)	possibly extirpated	none
28	Bonny Doon Ecological Reserve	6 (2022 natural), 83 (2022 experimental)	declining natural, reintroduction declined from 2021[1]	experimental reintroductions
29	Road Cut	35 (2012)	unknown	none
na	Suhr (Land Trust of Santa Cruz County)	15 (2018)	unknown	management plan
na	Pace	5-10 (2017)	unknown	none

[1]T. Kasteen pers. com. 2022, data; [2]McGraw and Jordan 2021, pp. 18-19; [3]Location is contiguous with Quail Hollow Quarry Conservation Areas, the low number of individuals is due to only a small portion of a larger population being captured based on property boundaries, management has increased the number of adult individuals (J. McGraw 2022 pers. com)

Restoration Efforts

Ben Lomond wallflower habitat enhancement and reintroduction efforts have been conducted at Quail Hollow Quarry, Zayante Sandhills Conservation Bank, and Bonny Doon Ecological Reserve (McGraw et al. 2020, entire; McGraw 2021, pp. 17-22; McGraw and Chrislock 2022, pp. 23-29). Habitat enhancement efforts have focused on evaluating mechanical disturbance primarily using tilling or raking of the soil to reduce litter and competing biomass, and to loosen compacted soil. Reintroduction by seeding and transplanting of greenhouse raised juvenile plants have also been evaluated.

A common finding across efforts was that tilled plots produced more plants that survived to reproduce than raked plots (McGraw et al. 2020, p. 47; McGraw 2021, p. ix). In a series of experimental enhancement and reintroductions, Ben Lomond wallflower demographic performance, including survivorship and reproduction, was greater in areas of loose sand soil created through digging and turning over the soil, or through installing seedlings in a hole dug with a trowel rather than inserting them into a dibble hole (McGraw 2021, p. ix). The mechanism for the benefits of loosening the soil are unknown, but are consistent with the species preferential occurrence in areas of disturbed soil such as slides and trails (McGraw 2004, pp. 244-249).

Approximately 11 percent of seedlings survived through two years (McGraw et al. 2020, pp. 52-53). Broadcast seeding was effective in producing many seedlings, but outplanted seedlings (those germinated in a greenhouse and then planted) survived to reproduce at higher rates than seedlings established *in situ* from broadcasted seed. Additionally, greenhouse reared seedlings with longer leaves more frequently survived to reproduce (McGraw et al. 2020, p. 56-57). Seedling survivorship was also correlated with greater soil moisture, suggesting that the plants may be limited by soil moisture and strongly affected by drought (McGraw et al. 2020, p. 51).

At Bonny Doon Ecological Reserve, the survival to reproduction of plants with one parent from Bonny Doon Ecological Reserve and one parent from a different population was greater than plants with local parents, or plants with parents from a different population. These results suggest potential inbreeding depression and do not provide evidence for local adaptation or outbreeding depression (McGraw et al. 2020, pp. 47, 60-61).

The control plots of the experimental reintroduction had no seed added, but litter was removed through raking and soil was disturbed through tilling. These plots did not produce individuals throughout the duration of the project, suggesting that there was no viable seed in the soil (McGraw et al. 2020, pp. 56-57). However, seedlings continued to be produced in areas that were seeded where plants survived to reproduce, further suggesting that introduction of seed and transplants is a necessary component of future reintroductions and may promote population persistence, though long-term monitoring is needed.

Evaluation of Threats

Habitat loss from sand quarries was the primary threat to Ben Lomond wallflower at the time of listing and was the dominant cause of habitat loss prior to listing (Service 1994, pp. 5504-5506). Residential development, fire suppression resulting in habitat conversion, and recreational activities and vandalism have also decreased the amount of suitable habitat for Ben Lomond wallflower (Service 1994, p. 5504-5506).

The recovery plan included agricultural conversion as a minor threat to Ben Lomond wallflower (Service 1998, p. 7). These threats were reiterated in the previous 5-year review, which found that the potential for new sand quarrying had decreased, while the loss of habitat due to fire suppression (resulting in the increase of woody shrub and tree cover) had increased (Service 2008, pp. 9-10, 13-14). Stochastic extirpation and herbivory were also introduced as threats in the 2008 5-year review (Service 2008, pp. 12, 14-15).

In this 5-year review, we reevaluate sand quarrying, fire suppression resulting in habitat conversion, the combined impacts of residential development, vandalism, and recreation, stochastic extirpation, agricultural conversion, and herbivory as threats to Ben Lomond wallflower. We also evaluate invasive species, inbreeding depression, and climate change as emerging threats.

Sand Quarrying

The Quail Hollow Quarry remains the only active sand quarry within the range of Ben Lomond wallflower. A long-term plan was developed to guide management and monitoring of multiple species, including Ben Lomond wallflower, at the Quail Hollow Quarry Conservation Areas, where work is ongoing (McGraw 2021, pp. v-xiii). The 2008 5-year review found that the threat of active sand quarrying had been reduced because mining was limited to a single operating quarry under the guidance of a habitat conservation plan (Service 2008, p. 9-10, 15). However, the amount of habitat lost from sand quarries has not been restored, resulting in lingering effects of past sand quarrying. For example, at the Olympia Quarry, exotic species cover and thin soils prevent the natural recolonization of Ben Lomond wallflower and its habitat, despite no active quarrying (McGraw and Chrislock 2019b, pp. iv-vii). At the Quail Hollow Quarry, populations had declined, necessitating active management, including reintroduction of Ben Lomond wallflower from the remaining on-site populations, to prevent extirpation. Monitoring and management of Ben Lomond wallflower reintroduction treatments is ongoing in the areas surrounding the active mining operations (McGraw 2021, pp. 17-22).

The habitat degradation resulting from sand quarrying will remain a threat to Ben Lomond wallflower if current and former quarries are not restored to habitat that is suitable for the species. The areas of current or former sand quarrying represent the best opportunity for recovery Ben Lomond wallflower and other federally endangered or threatened sandhills species.

Habitat restoration of the Olympia Quarry is ongoing. Ben Lomond wallflower is present on the margins of the former quarry but not in the area of active restoration. There has been some success reintroducing Ben Lomond spineflower (*Chorizanthe pungens* var. *hartwegiana*), a commonly co-occurring species, to the Olympia Quarry restoration areas, but restoration has not been implemented or monitored for long enough to determine if restoration efforts are successful (McGraw and Chrislock 2019b, pp. 12-20). It is likely that active maintenance of habitat degraded by sand quarries will be required to restore formerly suitable habitat.

Fire Suppression/Habitat Conversion

Fire exclusion has resulted in the loss of open sand habitat within sand parkland and sandhills chaparral by promoting establishment and growth of shrubs and trees that create shade and litter

that excluded Ben Lomond wallflower (McGraw 2004, pp. 25, 86-89). This has become an increasingly serious threat since listing (Service 1994, p. 5504; Service 2008, pp. 13-15). Data from the Quail Hollow Quarry Conservation Areas and Zayante Sandhills Conservation Bank have shown that Ben Lomond wallflower will decline if native and exotic vegetation, or litter, increase in the absence of disturbance (McGraw 2021, pp. 9-10; McGraw and Chrislock 2019a, pp. 14-15). Ben Lomond wallflower does not require fire for germination, but fire was likely the historical mechanism that maintained low vegetation cover in sandhill habitats (McGraw 2004, pp. 168-169). In the absence of fire, mechanical disturbance may result in similar reduction in competing biomass and may be more feasible in some circumstances than prescribed burns (McGraw and Chrislock 2020, pp. 22-28). However, the beneficial effects of vegetation removal either by mechanical means, prescribed fire, or natural fire, to increase gaps in sand parkland and sandhill chaparral may be short lived. In 2008, the Martin Fire burned large portions of the Bonny Doon Ecological Reserve, most of which had returned to pre-fire levels of canopy closure by 2020 (McGraw et al. 2020, p. 13).

Residential Development/Vandalism and Recreation

Recreation, private development, and vandalism result in habitat degradation and fragmentation (Service 2008, p. 10). Current levels of recreation are not monitored throughout the species' range, though recreation monitoring occurs at the Zayante Sandhills Conservation Bank and Quail Hollow Quarry Conservation Areas (McGraw and Chrislock 2022, p. 5; McGraw 2021, pp. 4-5, Appendix C). Mountain biking and hiking are the most likely forms of recreation to impact Ben Lomond wallflower and are present at many of the publicly accessible areas where the species occurs. Recreation disturbance can be both a threat and potentially beneficial to the species. Too frequent and intense disturbances will inhibit establishment and result in mortality of any plants present. The biennial life history of Ben Lomond wallflower increases the chance of mortality from recreational activities because plants usually take two years to reproduce. Infrequent and lower intensity disturbance may inhibit woody vegetation, exotic species, or reduce the amount of accumulated litter which could promote Ben Lomond wallflower, however any disturbance that is likely to inhibit woody vegetation establishment may also inhibit Ben Lomond wallflower establishment if the frequency and intensity is great enough. In general, the disturbance caused by established hiking and biking trails is too severe and too frequent to benefit Ben Lomond wallflower.

Current levels of private development and vandalism are not easily quantified. Historically, vandalism of Ben Lomond wallflower populations occurred in areas where the plant was seen as a barrier to development. The likelihood of this type of vandalism still occurring is unknown and, without consistent survey data throughout the range of the species, it may be difficult to differentiate between declines in abundance due to other threats or vandalism. Less malicious forms of vandalism are associated with residential areas that are adjacent to land that is under management for conservation of Ben Lomond wallflower. At the Zayante Sandhills Conservation Bank, dumping, creating defensible space, and ornamental landscaping historically occurred beyond the boundaries of private properties into the conservation area. This has been reduced through outreach and does not currently occur at levels warranting further action (McGraw and Chrislock 2022, pp. 7-8). The sandhill habitats where Ben Lomond wallflower occurs are regulated by Santa Cruz County and any new residential development would have

protections for Ben Lomond wallflower, although confidence in the effectiveness of this regulation is low (Service 2012, p. 13).

Stochastic Extirpation

Stochastic extirpation is a threat to Ben Lomond wallflower because of its limited range, small population sizes, and habitat fragmentation between occupied patches. Ben Lomond wallflower may be particularly susceptible to local extirpation by stochastic events because observational data suggest that a viable seed bank is lacking at declining populations, such as the Bonny Doon Ecological Reserve (Parker et al. 2011, pp. 9-11; McGraw et al. 2020, p. 56). The biennial life history, which requires plants to survive through summers with little to no precipitation and high temperatures to reproduce, also increases susceptibility to stochastic events because seed that germinates within one year may not survive to produce seed in the following year resulting in a depletion of any existing seed bank. Natural and experimental disturbances have failed to germinate seed that may be stored in a seedbank, further suggesting that a stochastic event may not be rescued through reestablishment from an existing seed bank (McGraw et al. 2020, p. 56).

Agricultural Conversion

The threat of agricultural conversion has been considered low since listing and no changes in agricultural pressure have developed since the previous 5-year review (Service 2008, p. 10). Grape production for winemaking and cannabis cultivation are potential agricultural activities that have impacted undeveloped areas in the region and could affect Ben Lomond wallflower or suitable habitat.

Herbivory

Herbivory was first observed as a threat to Ben Lomond wallflower in the 2008 5-year review (Service 2008, pp. 8-9). Since then, herbivory has likely contributed to population declines, as well as inhibited recovery and evaluation of recovery methods (due to loss of plants within experimental treatments). Pocket gophers, brush rabbits (*Sylvilagus bachmani*), mice (e.g., *Peromyscus* spp.), and black-tailed deer (*Odocoileus hemionus*) have been observed browsing the leaves or the flowering stalk of Ben Lomond wallflowers (McGraw and Chrislock 2019a, p. 15). Pocket gophers may consume the entire plant, as evidenced by a previously marked plant that was subsequently missing with a gopher mound in its place. Vegetative herbivory increases the likelihood that the plant will not survive to produce flowers. This exacerbates the already low rates of reproduction due to drought mortality. Plants that do survive to produce a flowering stalk are often grazed by black-tailed deer, which reduces the amount of seed produced (McGraw and Chrislock 2019a, p. 15). Herbivory appears to occur more frequently in sand chaparral habitat compared to sand parkland habitat, likely due to the cover that shrubs provide foraging herbivores from predators (e.g., raptors) (McGraw and Chrislock 2019a, p. 15). Herbivory from small mammals, as well as birds, occurred at the Bonny Doon Ecological Reserve despite efforts to protect plants from herbivory through caging (McGraw et al. 2020, p. 58).

Invasive Species

Invasive species outcompete Ben Lomond wallflower by decreasing the amount and size of vegetation gaps within sand chaparral and sand parkland habitat, as well as through shading and competition for nutrients and water (McGraw 2004, pp. 240-244, 253-254). Invasive species that have established within former sand quarries are difficult to control, making reintroduction and

recovery of Ben Lomond wallflower at those sites difficult. Portuguese broom (*Cytisus striatus*), French broom (*Genista monspessulana*), and silver wattle (*Acacia dealbata*) are three common woody invasive species that have been observed to establish rapidly in areas with low levels of disturbance (BEC 2021a, p. 6; BEC 2021b, p. 4; McGraw and Chrislock 2022, p. 4)). Once established, these and related species require annual removal efforts.

Sand chaparral and sand parkland soil is typically low nutrient, which may inhibit invasive herbaceous species colonization. Pollution may increase nitrogen deposition and increase the fertility of the nutrient-poor soils, facilitating the potential establishment of invasive species (McGraw 2019a, p. 39). Herbaceous exotic species such as rat-tail fescue, rip-gut brome, rattlesnake grass, smooth cat's ears, and sheep sorrel already constitute a major component of sand parkland habitat. These species are in lower densities in sand chaparral habitat (McGraw 2019a, pp. 7, 10-19). Complete removal of herbaceous exotic species is difficult due to established seed banks and presence in surrounding areas facilitating passive dispersal. Where herbaceous invasive species are limiting Ben Lomond wallflower presence continued active management will be required for recovery (McGraw and Chrislock 2022, pp. 4, 48, 53).

Inbreeding Depression

Most populations of Ben Lomond wallflower have declined since the species was listed in 1998 (Service 2008, p. 7). Current population numbers are relatively small and populations are likely isolated from one another due to topography, development, and distance, resulting in very low gene flow among populations. Because Ben Lomond wallflower is an obligate outcrosser, and is largely self-incompatible, populations must be large enough to reduce the chance of inbreeding depression, which can lower survivorship and decrease above-ground biomass (Melen et al. 2016, p. 1984). Bees, butterflies, and beetles are the most commonly observed Ben Lomond wallflower floral visitors (Melen et al. 2016, pp. 1982-1983). Of these, bees are the most common and foraging distances range from less than a quarter of a mile to several miles depending on the species of bee (Zurbuchen et al. 2010, pp. 671-672). Solitary bees typically have foraging distances around 0.25 mile compared to honey bees (*Apis mellifera*), which may have foraging distances of up to several miles (Beekman and Ratnieks 2000, pp. 671-672). An evaluation of seed production and genetic diversity within and between populations found that Ben Lomond wallflower was not pollen limited, suggesting that there are adequate pollinators to facilitate the greatest possible seed set (Melen et al. 2016, p. 1983). The same study found that the evaluated populations of Ben Lomond wallflower were experiencing inbreeding depression and that there was no evidence of local adaptation or outbreeding depression (Melen et al. 2016, pp. 1984, 1987-1988).

Climate Change

Ben Lomond wallflower may be affected by climate change most directly through changes in, and variability of, precipitation and minimum and maximum temperatures. Average precipitation is predicted to increase by 4.1 to 9.8 inches, minimum average temperature by 4.8 to 9.7 degrees Fahrenheit, and maximum average temperature by 4.4 to 7.0 degrees Fahrenheit by 2099 throughout Santa Cruz County (Langridge et al. 2018, pp. 13-17). Despite the predicted increase in precipitation, the areas occupied by Ben Lomond wallflower may experience fewer total days of precipitation relative to historical averages because of an associated increase in precipitation variability and timing. Current climate models suggest that there will be fewer days

of higher-than-average precipitation, leading to increased number of dry days between precipitation events (Langridge et al. 2018, p. 16). Because timing of precipitation impacts germination and survivorship, changes in variability and timing are likely to have a greater impact on the recovery of Ben Lomond wallflower than the predicted change in the amount of precipitation, or the increases in average minimum and maximum temperatures (McGraw and Jordan 2021, pp. 19-20). Current data suggest germination and survivorship are correlated with annual rainfall (McGraw and Jordan 2021, pp. 19-20). Periods of drought and increased temperatures may result in decreased soil moisture, decreasing the likelihood that seeds germinate, and juvenile plants survive to seed set.

Summary of Threats

The severity and type of threats have changed since the 2008 5-year review. No new sand quarries are proposed or expected, although the effects of past quarrying and current quarrying have contributed to habitat loss that requires restoration. Residential development, vandalism, and recreation are less severe threats than at time of listing although may still occur. Fire suppression resulting in habitat conversion, and herbivory are currently the most serious threats to the persistence and recovery of Ben Lomond wallflower. Increases in woody vegetation cover in the absence of periodic disturbance events is causing a reduction in suitable and occupied habitat for Ben Lomond wallflower through competition. Woody vegetation also provides refuge for herbivores from predators, increasing the potential for herbivory which is greatest in the sand chaparral habitat. Ben Lomond wallflower is typically susceptible to herbivory for two years until seed set and mortality prior to seed set may deplete the seed bank. Invasive species continue to establish in areas occupied by Ben Lomond wallflower, requiring active management to reduce the speed of establishment and loss of habitat. The potential for invasive plant species to colonize and spread within habitat suitable for Ben Lomond wallflower is greatest in the former quarries where soils have been altered (McGraw and Chris Lock 2019b pp. iv, 6). The small and declining population sizes at most locations have led to evidence of inbreeding depression. This, and the small population sizes, increase the vulnerability of Ben Lomond wallflower to extirpation from stochastic events. All threats are exacerbated by variability in precipitation patterns and drought. Again, the biennial life history increases Ben Lomond wallflower exposure to conditions that may cause mortality prior to seed set increasing the species vulnerability to negative climate patterns.

DOWNLISTING AND DELISTING CRITERIA

The following downlisting criteria were developed in the recovery plan for Ben Lomond wallflower and are paraphrased below (Service 1998, p. iv, 46):

1. The 17 currently known populations of Ben Lomond wallflower have been secured through fee-title acquisition, conservation easements, or habitat conservation plans.

2. Management plans for populations on Quail Hollow Ranch County Park and Bonny Doon Ecological Reserve are developed and being implemented.

3. Conservation measures for Ben Lomond wallflower are included in habitat conservation plans (Granite Rock Quarry, Kaiser Sand and Gravel Felton Plant, and the County of Santa Cruz) that have been developed and implemented for cooccurring insect species.

4. Population numbers are stable or increasing.

Delisting criteria may be considered when the downlisting criteria for a species has been met. The delisting criterion for Ben Lomond wallflower is (Service 1998, p. 47):

1. Threats are reduced or eliminated so that populations are capable of persisting without significant human intervention or perpetual endowments are secured for management necessary to maintain the continued existence of the species.

Evaluation

In this 5-year review we evaluate downlisting criteria 1 through 4. The delisting criterion is not evaluated until downlisting criteria have been met.

Downlisting Criterion 1
This criterion addresses the need to conserve Ben Lomond wallflower occurrences, but references mapping and occurrences that have since become out of date. The CNDDB currently recognizes 15 occurrences of Ben Lomond wallflower, while the recovery plan references 17 populations, and the previous 5-year review considered 20 populations. Current mapping is inaccurate for many occurrences and occurrences often include multiple landowners with different land uses and conservation practices due to how CNDDB applies occurrence numbers (all polygons within 0.25 mile of each other are grouped by a single occurrence number). This 5-year review considers 23 distinct locations that are differentiated from one another by ownership or management.

The intent of this criterion is to evaluate the amount of protected Ben Lomond wallflower populations. In this 5-year review, we evaluate the presence of current easements, management plans, and conservation ownership while acknowledging that there is a need for improved mapping accuracy and delineation of occurrences or populations.

There are currently 13 locations within five CNDDB occurrences that are managed for the conservation of Ben Lomond wallflower through a habitat conservation plan, long-term management plan, restoration plan, or are managed and monitored as part of a conservation easement (Table 1). Of the remaining 10 locations, one occurrence of Ben Lomond wallflower at Henry Cowell Redwoods State Park is unmanaged, but occurs on land that is not likely to be developed. Unfortunately, Ben Lomond wallflower may no longer occur there since no individuals were observed in 2003, though no formal surveys have been conducted. Similarly, a historical occurrence was vandalized to allow for development that never happened. That occurrence is now part of the Bonny Doon Ecological Reserve and while habitat is present, no individuals of Ben Lomond wallflower have been observed occurring outside of experimental reintroduction plots. Three additional occurrences on private land are believed to be possibly extirpated (Service 2008, pp. 7). The remaining five locations (within eight occurrences) all occur on private land with no recent information.

The number of populations that occur on land managed for the conservation of Ben Lomond wallflower has increased since the 2008 5-year review, but locations on private land, including some former quarries, remain unprotected. Additionally, Ben Lomond wallflower occurs at very low numbers or is declining at many of the protected locations despite management, restoration, and reintroductions. As a result, we consider that this criterion has not been met.

Downlisting Criterion 2

This criterion addresses specific proposed management plans that were expected to be completed when the recovery criteria were developed (Service 1998, p. 46). Management plans for Quail Hollow Ranch County Park and Bonny Doon Ecological Reserve were not developed. However, annual monitoring is conducted by the California Department of Fish and Wildlife at Quail Hollow Ranch County Park and experimental reintroductions and monitoring is occurring at Bonny Doon Ecological Reserve (Kasteen 2022, pers. com.). This criterion has not been met.

Downlisting Criterion 3
Ben Lomond wallflower is included in the habitat conservation plan for Quail Hollow Quarry where the species and known suitable habitat occurs and is managed in perpetuity. Ben Lomond wallflower is also included in the low effect habitat conservation plan for the San Lorenzo Valley Water District's Probation Tank Replacement Project where direct impacts to the species from the project were not anticipated. The conservation area established to mitigate the project does support a population (McGraw 2017, pp. 27, 31-39). A long-term management plan has also been developed for the Zayante Sandhills Conservation Bank and for properties managed by the Land Trust of Santa Cruz County that support, or could support, Ben Lomond wallflower (McGraw 2006, entire; McGraw 2019, entire).

The intent of this criterion is to ensure that Ben Lomond wallflower is included in future conservation plans that may be required due to presence of co-occurring federally listed insect species. Because sandhills habitat is rare in Santa Cruz County, and is a protected habitat type under County jurisdiction, it is expected that any permits or conservation measures developed for co-occurring species are also likely to include conservation measures for Ben Lomond wallflower by County regulation. Because we expect that Ben Lomond wallflower will be included in future conservation plans where appropriate and it has been included in conservation plans already developed, we consider this criterion to be partially met.

Downlisting Criterion 4
Population data are not available at all locations and the available data were collected using different methods and often looking at different parameters (e.g. percent cover, acreage occupied, frequency of occurrence etc.). The available data suggest that populations of Ben Lomond wallflower are declining at a majority of locations or there are no recent data for which to evaluate population trends. Declines of Ben Lomond wallflower have been attributed to drought, herbivory, and increases in woody vegetation cover. These factors are difficult to manage even as funding and expertise are available. Additionally, we assume that populations with no data are likely declining as well, since they are unmanaged and subject to the same threats.

The abundance of reproducing plants at all locations is low relative to the time of listing. This has likely led to inbreeding depression in small populations. Studies evaluating the presence of a seed bank have found that there is very low to no seed even in areas immediately adjacent to reproducing plants. Therefore, we consider that this criterion has not been met due to low numbers of reproducing adults and the observed lack of a robust seed bank throughout a majority of the species range.

CONCLUSION

The evaluation of threats affecting Ben Lomond wallflower under the factors in 4(a)(1) of the Act, recovery criteria, and current understanding of population trends, were conducted using the best available scientific information. The threat of active sand quarrying has decreased since listing and the previous 5-year review, although the potential for redevelopment, habitat degradation, introduction of invasive species, and population fragmentation resulting from past and current sand quarrying persists. Agricultural conversion remains a low but on-going threat. Fire suppression and resulting habitat conversion, and herbivory have increased in severity and are associated with declines in abundance. Inbreeding depression, climate change, and invasive species are newly considered threats that have immediate, as well as long term, negative effects on recovery. Small population sizes and depleted seed banks contribute to the likelihood of stochastic extinction. Reintroduction and restoration efforts have maintained or increased populations at the Quail Hollow Conservation Areas, Bonny Doon Ecological Reserve, and Zayante Sandhills Conservation Bank, but populations continue to decline at nearly all other locations. Therefore, we conclude that Ben Lomond wallflower remains an endangered species.

RECOMMENDATIONS FOR FUTURE ACTIONS

1. Conduct surveys throughout the range of Ben Lomond wallflower to create a detailed and reliable map of occupied areas and suitable but unoccupied habitat.
2. Conduct reintroduction at locations in addition to Bonny Doon Ecological Reserve throughout the range of the species to increase abundance and evaluate site specific conditions that may beneficial or detrimental to establishment. Former sand quarries should be priority locations.
3. Implement herbivory protection measures throughout the range of the species to ensure that some plants at each location will survive to seed set.
4. Manage disturbance to decrease woody vegetation, litter, and invasive species, and create loose soil conditions that promote Ben Lomond wallflower.
5. Secure funding to support management and annual monitoring at all protected Ben Lomond wallflower locations.
6. Protect additional unprotected habitat and/or develop agreements with landowners to promote population expansion.

APPROVAL

Lead Field Supervisor, Fish and Wildlife Service

Approved STEPHEN HENRY Digitally signed by STEPHEN HENRY Date: 2022.08.23 11:30:51 -07'00'

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