5-YEAR REVIEW

Vail Lake ceanothus (*Ceanothus ophiochilus*)

GENERAL INFORMATION:

Species: *Ceanothus ophiochilus*

Date listed: October 13, 1998

FR citation(s): USFWS 1998 (63 FR 54956–54971)

Classification: Threatened

BACKGROUND:

Most recent status review:

The U.S. Fish and Wildlife Service (USFWS, we) completed a 5-year review for *Ceanothus ophiochilus* on June 17, 2013 (USFWS 2013a). We recommended no change in listing status.

FR Notice citation announcing this status review:

On January 27, 2020, we published a *Federal Register* notice announcing initiation of the 5-year review of this species, and the opening of a 60-day comment period to receive information (USFWS 2020, pp. 4692–4694). We received no information about *Ceanothus ophiochilus*.

ASSESSMENT:

Information acquired since the last status review:

This 5-year review was conducted by the U.S. Fish and Wildlife Service's Carlsbad Fish and Wildlife Office. Data for this review were solicited from interested parties through a *Federal Register* notice announcing this review on January 27, 2020. Additionally, we conducted a literature search and a review of information in our files.

SUMMARY OF NEW INFORMATION SINCE 2013:

Biology and distribution

Since 2013, *Ceanothus ophiochilus* has been mentioned in several studies. Burge *et al.* (2011) included *C. ophiochilus* samples in a study of *Ceanothus* diversification in the California Floristic Province. Diversification of the two *Ceanothus* subgenera began approximately 6 million years ago (early Pliocene), before the origin of the Mediterranean climate in California (p. 1157). In a taxonomic overview of *Ceanothus* subgenus *Cerastes,* Burge *et al.* (2015, p. 958) noted that putative hybrids between *C. ophiochilus* and *C. crassifolius* needed further study, as some specimens resembled *C. bolensis.* And in a description of three new *Ceanothus*, Burge *et* *al.* (2017, p. 530, Table 1) listed *C. ophiochilus* as one of 19 edaphic-endemic *Ceanothus* within the California Floristic Province. Of the new studies since 2011, none focused on *C. ophiochilus* or contained new information about *C. ophiochilus* biology or life history.

Several other studies have provided new information about plants with functional traits similar to *Ceanothus ophiochilus*. Venturas *et al.* (2016) studied chaparral shrub mortality during a drought in 2014 (see discussion in Appendix II). Bonebrake *et al.* (2014, pp. 1058, 1059) modeled the effects of threats and different conservation strategies—including land conservation, managed relocation, and fire management—on long-lived, obligate seeding shrubs in Mediterranean shrublands, using *C. verrucosus* as a representative species. In their model scenarios, frequent fire had the greatest impact on *C. verrucosus*. They also suggested that managed relocation of seed (movement of seeds outside of the historical range) could effectively reduce future *C. verrucosus* population decline (p. 1065).

The Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP) Biological Monitoring Program (BMP) monitors rare plant occurrences within the MSHCP Conservation Area (BMP 2017, p. iii). In 2014, the BMP monitored two *Ceanothus ophiochilus* occurrences, California Natural Diversity Database (CNDDB) EOs 2 and 3 (BMP 2015, pp. 8, 24). One location reported as a new site (CEOP-4) in 2014 is within the boundaries of CNDDB EO 3 (BMP 2015, Appendix C, p. 24; CDFW 2020; Drennen 2020a, pers. comm.). Monitoring for *C. ophiochilus* is on an 8-year monitoring cycle and so occurrences were not monitored for the last several years (2015–2019; BMP 2016; BMP 2017; BMP 2018; BMP 2019; Drennen 2020b, pers. comm.).

In summary, *Ceanothus ophiochilus* has been noted in two studies of *Ceanothus* since 2013 (Burge *et al.* 2015; Burge *et al.* 2017), and other studies (Bonebrake *et al.* 2014; Venturas *et al.* 2016) have provided information about shrub species with similar functional traits (i.e., obligate seeders) to *C. ophiochilus*. However, since 2013, there has been no new information that changes our understanding of *C. ophiochilus* biology or spatial distribution, and so the information in our 2013 review remains accurate.

Threats

Our 2013 5-year review discussed potential threats to *Ceanothus ophiochilus* from: 1) urban development, 2) invasive nonnative plants, 3) wildland fire and fire management, 4) hybridization/introgression, and 5) climate change. Two other potential threats (vandalism and recreational activities) were discussed, but were not considered present in 2013 (Appendix A, Table A1).

This section and Appendix B summarize new information about threats to *C. ophiochilus* since 2013. The new information relates to:

1. A programmatic Biological Opinion we issued in 2013,

2. The threat of urban development at Vail Lake, and

3. The threat of climate change and potential effects to *C. ophiochilus*.

Revised Land Management Plans

In 2013, we issued a programmatic Biological Opinion for the Revised Land Management Plans for four Southern California National Forests (USFWS 2013b, entire). We discussed the general effects of eight U.S. Forest Service (Forest Service) activities on plants, and specific effects to *Ceanothus ophiochilus* (pp. 121–124). Standards in the Biological Opinion are to be implemented to minimize impacts to the species and its habitat where *C. ophiochilus* occurs. We determined that the implementation of the Revised Land Management Plans for the four southern California National Forests was not likely to jeopardize the continued existence of *C. ophiochilus*, or result in the destruction or adverse modification of its designated critical habitat. We reached that conclusion because 1) no new permanent loss of occupied or designated critical habitat was expected under the Forest Plan; 2) impacts were expected to be avoided for most areas; 3) anticipated low level impacts would not result in a reduction of *C. ophiochilus* on Forest Service lands or rangewide; and 4) impacts would not affect conservation or species recovery (p. 124). Therefore we do not anticipate an appreciable reduction in the number or distribution of plants on Forest Service lands (USFWS 2013b, p. 123).

Urban development

In 2014, the Rancho California Water District (RCWD) acquired the lands encompassing the Vail Lake occurrence of *Ceanothus ophiochilus.* The area is not under permanent conservation (for example, through conservation easement). However, according to the Property Guidance Document prepared by RCWD (RCWD 2016, Volume I), the vision for the property is to "protect and enhance RCWD's water resources, to preserve the biological resources through habitat conservation and restoration, and to provide a variety of appropriate land- and water-based recreational opportunities in a fiscally prudent manner," and management objectives include habitat conservation and restoration (RCWD 2016, p. 6). Due to the acquisition of the Vail Lake property by RCWD, the threat of residential development is no longer present at the Vail Lake occurrence of *C. ophiochilus*.

As in the 2013 5-year review, the indirect effects of urban development could impact *C. ophiochilus* at the Agua Tibia Wilderness–North occurrence (CNDDB EO 2) (USFWS 2013a, pp. 13–14, 40).

Climate change

New information about climate change has become available since 2013, and is summarized in Appendix B. The new information does not alter the conclusion of our 2013 5-factor analysis, in which we considered climate change a rangewide threat to *C. ophiochilus* individuals and habitat.

Summary

Since the 2013 5-year review, acquisition of the Vail Lake occurrence of *Ceanothus ophiochilus* has partially ameliorated the threat of residential development, improving the condition of the species in regards to this threat (Appendix A, Table A1). Although new climate modeling has provided updated future projections of temperature, precipitation, and wildfire for southern California, the response of *C. ophiochilus* to those changing conditions remains uncertain

(Appendix A, Table A1). We received no new information about any other threats to the species, so the information in our 2013 5-factor analysis remains accurate.

CONCLUSION:

After reviewing the best available scientific information, we conclude that *Ceanothus ophiochilus* remains a threatened species. The evaluation of threats affecting the species under the factors in 4(a)(1) of the Act, and analysis of the status of the species in our 2013 status review (USFWS 2013a), remains an accurate reflection of the species' current status.

RECOMMENDATIONS FOR FUTURE ACTIONS:

1. Work with the Rancho California Water District to conserve and enhance the Vail Lake occurrence of *Ceanothus ophiochilus*.

2. Survey suitable habitat for new occurrences of *C. ophiochilus.*

3. Survey for nonnative invasive plants in the vicinity of *C. ophiochilus* occurrences.

4. Model *C. ophiochilus* habitat under a range of future climate scenarios, and evaluate assisted migration or translocation as a management strategy.

5. Determine the current level and extent of introgression of *C. ophiochilus* with *C. crassifolius*, and reexamine putative hybrids.

6. Collect additional *C. ophiochilus* seeds for *ex situ* storage at a certified Center for Plant Conservation facility.

Lead Field Supervisor, Fish and Wildlife Service

☒ Approve

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Appendices

REFERENCES CITED

Ainsworth, E.A. and S.P. Long. 2005. What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. New Phytologist 165:351–372.

BMP. [Biological Monitoring Program]. 2015. Western Riverside County MSHCP Biological Monitoring Program 2014 rare plants survey report. Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan, 36 pp.

BMP. [Biological Monitoring Program]. 2016. Western Riverside County Multiple Species Habitat Conservation Plan Biological Monitoring Program 2015 rare plant survey report. Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan, Riverside CA, 37 pp.

BMP. [Biological Monitoring Program]. 2017. Western Riverside County Multiple Species Habitat Conservation Plan Biological Monitoring Program 2016 rare plant survey report. Prepared from the Western Riverside County Multiple Species Habitat Conservation Plan, 32 pp.

BMP. [Biological Monitoring Program]. 2018. Western Riverside County Multiple Species Habitat Conservation Plan Biological Monitoring Program 2017 rare plant survey report. [Biological Monitoring Program], Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan. 58 pp.

BMP. [Biological Monitoring Program]. 2019. Western Riverside County Multiple Species Habitat Conservation Plan Biological Monitoring Program 2018 rare plant survey report. [Biological Monitoring Program], Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan. 70 pp.

Bonebrake, T.C., A.D. Syphard, J. Franklin, K.E. Anderson, H.R. Akcakaya, T. Mizerek, C. Winchell, and H.M. Regan. 2014. Fire management, managed relocation, and land conservation options for long-lived obligate seeding plants under global changes in climate, urbanization, and fire regime. Conservation Biology 28:1057–1067.

Boyd, S. and D.L. Banks. 1995. A botanical assessment of the Agua Tibia Wilderness Area, Cleveland National Forest, California. Rancho Santa Ana Botanic Garden, 78 pp.

Boyd, S., T. Ross, and L. Arnseth. 1991. *Ceanothus ophiochilus* (Rhamnaceae): a distinctive, narrowly endemic species from Riverside County, California. Phytologia 70:28–41.

Burge, D.O., D.M. Erwin, M.B. Islam, J. Kellermann, S.W. Kembel, D.H. Wilken, and P.S. Manos. 2011. Diversification of *Ceanothus* (Rhamnaceae) in the California Floristic Province. International Journal of Plant Sciences 172:1137–1164.

Burge, D.O., J.P. Rebman, M.R. Mulligan, and D.H. Wilken. 2017. Three edaphic-endemic *Ceanothus* (Rhamnaceae) new to science. Systematic Botany 42:529–542.

Burge, D.O., K. Zhukovsky, and D. Wilken H. 2015. A taxonomic conspectus of *Ceanothus* Subgenus *Cerastes* (Rhamnaceae). Systematic Botany 40:null.

Cal-Adapt. 2020. LOCA Downscaled Climate Projections (Scripps Institution of Oceanography), Gridded Historical Observed Meterological Data (University of Colorado, Boulder). Website viewed Retrieved April 7, 2020.

CDFW [California Department of Fish and Wildlife]. 2020. California Natural Diversity Database. California Department of Fish and Wildlife.

Damschen, E.I., S. Harrison, D.D. Ackerly, B.M. Fernandez-Going, and B.L. Anacker. 2012. Endemic plant communities on special soils: early victims or hardy survivors of climate change? Journal of Ecology 100:1122–1130.

Damschen, E.I., S. Harrison, and J.B. Grace. 2010. Climate change effects on an endemic-rich edaphic flora: resurveying Robert H. Whittaker's Siskiyou sites (Oregon, USA). Ecology 91:3609–3619.

D'Antonio, C.M. and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology, Evolution, and Systematics 22:63–87.

Dettinger, M. 2011. Climate Change, Atmospheric Rivers, and Floods in California - A Multimodel Analysis of Storm Frequency and Magnitude Changes1. JAWRA Journal of the American Water Resources Association 47:514-523.

Fernandez-Going, B.M., B.L. Anacker, and S.P. Harrison. 2012. Temporal variability in California grasslands: Soil type and species functional traits mediate response to precipitation. Ecology 93:2104–2114.

Grime, J.P., J.D. Fridley, A.P. Askew, K. Thompson, J.G. Hodgson, and C.R. Bennett. 2008. Long-term resistance to simulated climate change in an Infertile grassland. Proceedings of the National Academy of Sciences of the United States of America 105:10028–10032.

Grime, J.P., V.K. Brown, K. Thompson, G.J. Masters, S.H. Hillier, I.P. Clarke, A.P. Askew, D. Corker, and J.P. Kielty. 2000. The response of two contrasting limestone grasslands to simulated climate change. Science 289:762–765.

Hall, A., N. Berg, and K. Reich. 2018. Los Angeles region report. California's Fourth Climate Change Assessment. Publication number: SUM-CCCA4-2018-007, 97 pp.

Hamerlynck, E.P., T.E. Huxman, R.S. Nowak, S. Redar, M.E. Loik, D.N. Jordan, S.F. Zitzer, J.S. Coleman, J.R. Seemann, and S.D. Smith. 2000. Photosynthetic responses of *Larrea tridentata* to a step-increase in atmospheric CO2 at the Nevada Desert FACE Facility. Journal of Arid Environments 44:425–436.

Harrison, S., E. Damschen, B. Fernandez-Going, A. Eskelinen, and S. Copeland. 2015. Plant communities on infertile soils are less sensitive to climate change. Annals of Botany 116:1017–1022.

He, M. and M. Gautam. 2016. Variability and trends in precipitation, temperature and drought indices in the State of California. Hydrology 3:14.

Hughes, L. 2000. Biological consequences of global warming: is the signal already apparent? Tree 15:56–61.

Hughes, M. and A. Hall. 2010. Local and synoptic mechanisms causing southern California's Santa Ana winds. Climate Dynamics 34:847–857.

IPCC. [Intergovernmental Panel on Climate Change]. 2013. Summary for Policymakers. Pages 3–29 *in* Climate change 2013: the physical science basis, T.F. Stocker, D. Qin, G-K Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley(Eds.). Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, New York, USA.

IPCC. [Intergovernmental Panel on Climate Change]. 2014. Summary for policymakers. Pages 32 *in* Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspacts. Contribution of Working Group II to the Fifth Assessement Report of the Intergovernmental Panel on Climate Change, C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, *et al* (Eds.). Cambridge University Press. Cambridge, United Kingdom and New York, New York, USA. *http://energieclimat.hypotheses.org/20557*.

Jin, Y., M.L. Goulden, N. Faivre, S. Veraverbeke, F. Sun, A. Hall, M.S. Hand, S.J. Hook, and J.T. Randerson. 2015. Identification of two distinct fire regimes in Southern California: implications for economic impact and future change. Environmental Research Letters 10:1–12.

Kalansky, J., D. Cayan, K. Barba, L. Walsh, K. Brouwer, and D. Boudreau. 2018. San Diego summary report. California's Fourth Climate Change Assessment. Publication number: SUM-CCCA4-2018-009, 114 pp.

Lenoir, J., J.C. Gegout, P.A. Marquet, P. de Ruffray, and H. Brisse. 2008. A Significant Upward Shift in Plant Species Optimum Elevation During the 20th Century. Science 320:1768–1771.

Lindsey, R. 2020. Climate change: atmospheric carbon dioxide. Website viewed Retrieved April 9, 2020.

Loarie, S.R., B.E. Carter, K. Hayhoe, S. McMahon, R. Moe, C.A. Knight, and D.D. Ackerly. 2008. Climate change and the future of California's endemic flora. PloS One 3:e2502.

Loarie, S.R., P.B. Duffy, H. Hamilton, G.P. Asner, C.B. Field, and D.D. Ackerly. 2009. The velocity of climate change. Nature 462:1052–1055.

Naumburg, E., D.C. Housman, T.E. Huxman, T.N. Charlet, M.E. Loik, and S.D. Smith. 2003. Photosynthetic responses of Mojave Desert shrubs to free air CO2 enrichment are greatest during wet years. Global Change Biology 9:276–285.

Parmesan, C. 2005. Biotic response: range and abundance changes. Pages 41–55 *in* Climate change and biodiversity, T.E. Lovejoy and Lee Hannah(Eds.). Yale University Press. New Haven, Connecticut, USA and London, United Kingdom.

Pierce, D.W., J.F. Kalansky, and D.R. Cayan. 2018. Climate, drought, and sea level rise scenarios for California's Fourth Climate Change Assessment. California's Fourth Climate Change Assessment, California Energy Commission.

Polade, S.D., A. Gershunov, D.R. Cayan, M.D. Dettinger, and D.W. Pierce. 2017. Precipitation in a warming world: Assessing projected hydro-climate changes in California and other Mediterranean climate regions. Scientific Reports 7:10783-10.

RCWD. [Rancho California Water District]. 2016. Vail Property and Sundance Ranch Property Final Property Guidance Document, Volume I. 35 pp.

Riordan, E.C., A.M. Montalvo, and J.L. Beyers. 2018. Using Species Distribution Models with climate change scenarios to aid ecological restoration decisionmaking for southern California shrublands. Pacific Southwest Research Station, Research Paper PSW-RP-270, U.S. Department of Agriculture.

Root, T.L. and L. Hughes. 2005. Present and future phenological changes in wild plants and animals. Pages 61–67 *in* Climate change and biodiversity, T.E. Lovejoy and Lee Hannah(Eds.). Yale University Press. New Haven, Connecticut, USA and London, UK.

Slade, N.A., J.S. Horton, and H.A. Mooney. 1975. Yearly Variation in the Phenology of California Annuals. The American Midland Naturalist 94:209–214.

Smith, W.K., T.C. Vogelmann, E.H. DeLucia, D.T. Bell, and K.A. Shepherd. 1997. Leaf form and photosynthesis. BioScience 47:785–793.

Soroye, P., T. Newbold, and J. Kerr. 2020. Climate change contributes to widespread declines among bumble bees across continents. Science (New York, N.Y.) 367:685-688.

Swain, D.L., B. Langenbrunner, J.D. Neelin, and A. Hall. 2018. Increasing precipitation volatility in twenty-first-century California. Nature Climate Change 8:427-433.

Taiz, L. and E. Zeiger. 2010. Plant physiology. 5th edition. Sinauer Associates, Inc. Sunderland, Maryland, USA. 782 pp.

Theurillat, J. and A. Guisan. 2001. Potential impact of climate change on vegetation in the European Alps: a review. Climate Change 50:77–109.

Thomas, C.D. 2005. Recent evolutionary effects of climate change. Pages 75–88 *in* Climate change and biodiversity, T.E. Lovejoy and Lee Hannah(Eds.). Yale University Press. New Haven, Connecticut, USA and London, United Kingdom.

USFWS. U.S. Fish and Wildlife Service. 2008. Vail Lake ceanothus (*Ceanothus ophiochilus*) 5-year review: summary and evaluation. Carlsbad Fish and Wildlife Office, Department of the Interior. 20 pp.

USFWS. [U.S. Fish and Wildlife Service]. 2013a. *Ceanothus ophiochilus* (Vail Lake Ceanothus) 5-year review: summary and evaluation. Carlsbad Fish and Wildlife Office, Department of the Interior. 41 pp.

USFWS. [U.S. Fish and Wildlife Service]. 2013b. Programmatic Biological Opinion for the Revised Land Management Plans for the four Southern California National Forests, California. Carlsbad and Ventura Fish and Wildlife Offices, Department of the Interior. 337 pp.

USFWS. [U.S. Fish and Wildlife Service]. 2020. Endangered and threatened wildlife and plants; initiation of 5-year status reviews of 66 plant species in California and Nevada. Federal Register 85:4692–4694.

van Vurren, D.P., J. Edmonds, M. Kainuma, K. Riahi, A. Thomson, K. Hibbard, G.C. Hurtt, T. Kram, V. Krey, J. Lamarque, T. Masui, M. Meinshausen, N. Nakicenovic, S.J. Smith, and S.K. Rose. 2011. The representative concentration pathways: an overview. Climatic Change 109:5–31.

van Wagtendonk, J.W. 2006. Fire as a physical process. Pages 38–57 *in* Fire in California's ecosystems, N.G. Sugihara, Jan W. van Wagtendonk, Kevin E. Shaffer, Joann Fites-Kaufman and Andrea E. Thode(Eds.). University of California Press. Berkeley and Los Angeles, California.

Venturas, M.D., E.D. MacKinnon, H.L. Dario, A.L. Jacobsen, R.B. Pratt, and S.D. Davis. 2016. Chaparral shrub hydraulic traits, size, and life history types relate to species mortality during California's historic drought of 2014. Plos One 11:e0159145.

Westerling, A.L. 2018. Wildfire simulations for California's Fourth Climate Change Assessment: projecting changes in extreme wildfire events with a warming climate. California's Fourth Climate Change Assessment, California Energy Commission.

Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30:279–338.

PERSONAL COMMUNICATION

Drennen, K. 2020a. Data Manager, Biological Monitoring Program. Email correspondence to Mary Crawford, Fish and Wildlife Biologist, Carlsbad Fish and Wildlife Office. Subject: Question about Vail Lake ceanothus occurrence. Dated: April 9, 2020.

Drennen, K. 2020b. Data Manager, Biological Monitoring Program. Email correspondence to Mary Crawford, Fish and Wildlife Biologist, Carlsbad Fish and Wildlife Office. Subject: Availability of 2018 Biological Monitoring Report. Dated: April 29, 2020.

APPENDIX A

Summary of Threat Changes Between 2013 And 2020

Table A1: Summary of changes between 2013 and 2020 regarding threats to *Ceanothus ophiochilus*

Threat factor	**Threat name**	**2013 conclusion**	**2020 conclusion**	**Summary of change between 2013 and 2020**	**Change in condition between 2013 and 2020**
A	Urban development	Urban development is a potential threat at 2 of 3 occurrences: Agua Tibia Wilderness - North and Vail Lake. However, the threat is not imminent.	Urban development is a potential threat on private lands at Agua Tibia Wilderness - North. The threat is very likely ameliorated at Vail Lake, which has been acquired by RWCD.	Impacts from residential development are likely reduced and are no longer likely a threat at Vail Lake. As in 2013, development is a threat at EO 2 (Agua Tibia Wilderness-North).	Improved
A	Recreational activities	Recreational activities are not a threat at any occurrences due to location and limited access.	No new information about recreational activities at any occurrence.	No change from 2013.	Not applicable
A	Invasive nonnative plants	Invasive nonnative plants are not a currently a threat, but changes in fire frequency could increase future threats	No new information about invasive nonnative plants at any occurrence	No change from 2013	Not applicable
A	Wildland fire and fire management	Future vegetation management and fire suppression activities could impact the species and are a primary threat to *Ceanothus ophiochilus* and its habitat, but the threat has been reduced since listing due to protective measures put in place by the Forest Service.	Under the 2013 Biological Opinion, future impacts will be restricted to existing uses. Neither the Wildland Urban Interface (WUI) Defense Zone, nor existing fuelbreaks overlap with existing *Ceanothus ophiochilus* occurrences or habitat, but future treatments outside those areas could have short-term impacts to the species.	No change from 2013.	Not applicable

Threat factor	**Threat name**	**2013 conclusion**	**2020 conclusion**	**Summary of change between 2013 and 2020**	**Change in condition between 2013 and 2020**
B	Overutilization	Overutilization is not a threat to *Ceanothus ophiochilus*	No new information about overutilization	No change from 2013	Not applicable
C	Disease	Disease is not a threat to *Ceanothus ophiochilus*	No new information about disease	No change from 2013	Not applicable
C	Predation	Predation is not a threat to *Ceanothus ophiochilus*	No new information about predation	No change from 2013	Not applicable
E	Vandalism	Vandalism is not a threat to *Ceanothus ophiochilus*	No new information about vandalism	No change from 2013	Not applicable
E	Hybridization and introgression	It is not clear whether hybridization/introgression is a threat to *Ceanothus ophiochilus*	No new information about hybridization or introgression	No change from 2013	Not applicable
E	Climate change	Climate change is a rangewide threat to *Ceanothus ophiochilus*	New information about climate change is available from California's Fourth Climate Assessment and downscaled models, refer to Appendix B	No change from 2013: New information about climate change summarized in Appendix B, but no clear direction of impacts to *Ceanothus ophiochilus* (i.e., improving or worsened)	Unknown

APPENDIX B

Summary of New Climate Change Information

This appendix summarizes new information about climate change in southern California, and possible effects to *Ceanothus ophiochilus*.

Representation Concentration Pathways (RCPs) describe different future scenarios of greenhouse gas emissions and atmospheric concentrations, air pollutant emissions, and land use (IPCC 2014, p. 57). No likelihood is attached to any of the RCPs (van Vurren *et al.* 2011, p. 26); that is, a stringent mitigation scenario (RCP 2.6) is no more or less likely than a high emissions scenario (RCP 8.5), and vice versa.

TEMPERATURE

Temperature across southern California has increased over the past century. He and Gautam (2016) analyzed 1896–2015 temperature records for the region. They reported that annual average, maximum, and minimum temperature all increased by around 0.16 degree Celsius per decade (p. 11).

Projected temperature increases differ spatially across southern California. The ocean buffers warming near the coast, so coastal areas are projected to experience relatively smaller temperature increases (Hall *et al.* 2018, p. 11). But inland areas—such as the range of *Ceanothus ophiochilus* in western Riverside County—are projected to have relatively larger temperature changes under both emissions scenarios (Hall *et al.* 2018, p. 11). Extremely hot days are also projected to become more frequent and intense, with the largest changes in interior regions (Hall *et al.* 2018, p. 11).

For the range of *Ceanothus ophiochilus* in Western Riverside County, annual average maximum temperatures under RCP 4.5 are projected to increase from an observed historical (1961–1990) average of 77.2 degrees Fahrenheit (F) [25.1 degrees Celsius (C)] (range 75.8–80.0 degrees F, 24.3–26.7 degrees C), to a projected future (2070–2099) average of 82.9 degrees F (28.3 degrees C) (range 79.8 –86.0 degrees F, 26.5–30.0) (Cal-Adapt 2020). Under RCP 8.5, end-of-century (2070–2099) annual average maximum temperatures are projected to rise to 85.7 degrees F (29.8 degrees C) (range 81.4–90.6 degrees F, 27.4–32.5 degrees C). For projections of future temperature, RCP 4.5 and 8.5 scenarios are similar in the early and mid-21st century. Projections diverge in the second part of the century, as emissions continue to rise under RCP 8.5 (Hall *et al.* 2018, p. 10).

PRECIPITATION

Precipitation in southern California is highly variable from year to year (Kalansky *et al.* 2018, p. 24; Hall *et al.* 2018, p. 12). Models of future precipitation generally project small mean changes relative to the historical variability, and the overall direction of future precipitation is unclear (Hall *et al.* 2018, p. 13). Models do project increases in extreme precipitation frequency and intensity (Polade *et al.* 2017, p. 7; Swain *et al.* 2018, p. 428), including increases in the frequency of atmospheric-river storms, which deliver intense precipitation and can cause severe flooding (Dettinger 2011, p. 519). However, droughts are also projected to become more frequent and intense, and will be exacerbated by higher temperatures (Kalansky *et al.* 2018, p. 25).

ATMOSPHERIC CO_2 CONCENTRATION

Since 1750, the atmospheric concentrations of greenhouse gasses (including carbon dioxide, methane, and nitrous oxide) have increased because of human activity (IPCC 2013, p. 11). In 2011, the concentration of carbon dioxide (CO_2) was 391 parts per million (ppm), 40 percent higher than pre-industrial levels (IPCC 2013, p. 11). In 2018, the global average atmospheric carbon dioxide (CO_2) concentration was 407.4 parts per million (ppm) (Lindsey 2020).

Plants use CO_2 and water to synthesize carbohydrates. Therefore, elevated CO_2 concentrations can directly affect photosynthesis.

FIRE

California has a Mediterranean climate with cool, wet winters and hot, dry summers. Fire is an important part of California ecosystems. Fire behavior is influenced by topography, weather, fuel characteristics, and ignition sources (van Wagtendonk 2006, pp. 38–46). Santa Ana winds—strong, dry, and hot winds occurring mostly in September through December (Hughes and Hall 2010, p. 847; Jin *et al.* 2015, pp. 1–2)—are one feature of the southern California climate which can influence wildfire behavior and size. Wildfires driven by Santa Ana winds (Santa Ana fires) spread more quickly, and have higher intensity, than fires that occur outside the Santa Ana season (Jin *et al.* 2015, pp. 5–6). For California's Fourth Climate Assessment, Pierce *et al.* (2018) projected an increase in the driest of Santa Ana days (daily wind speeds greater than or equal to 8 meters per second, and less than or equal to 20 percent relative humidity), although the number of Santa Ana days and the days with the strongest wind speeds were projected to decrease (Pierce *et al.* 2018, p. 36; Kalansky *et al.* 2018, p. 27).

There is uncertainty in future wildfire projections for southern California (Hall *et al.* 2018, p. 18), but wildfire risk will likely increase as climate warms (Kalansky *et al.* 2018, p. 6). Under RCP 8.5, Westerling (2018, p. 19) projected an increasing tendency towards extreme wildfire events, rapidly accelerating after the mid-21st century. Statewide, the greatest increases in burned area were projected to be in forested areas of the state (Westerling 2018, p. 14). For southern California under RCP 8.5, Jin *et al.* (2015, p. 9–10) projected increases in burned area, number of fires, and fire size for both Santa Ana and non-Santa Ana fires.

POTENTIAL EFFECTS ON *CEANOTHUS OPHIOCHILUS*

There is uncertainty both in projections of future climate, and in the response of species to projected changes. Plants may persist in a modified climate, move to areas of more suitable climate, or go extinct (Theurillat and Guisan 2001, p. 78; Parmesan 2005, pp. 48–52). Hughes (2000, entire) identified four broad categories of climate change effects on species:

1. Physiological effects, caused by changes in precipitation, temperature, and atmospheric CO_2 concentration. In plants, those variables affect photosynthesis and respiration.
2. Effects on species distributions due to increased temperature. Species are expected to shift towards higher latitudes and elevations.
3. Phenological effects, including alteration of environmental cues, such as temperature and resource availability.
4. *In situ* adaptation, in which species evolve to adapt to changing conditions.

These effects could cause further changes in species interactions (for example, phenological changes could alter the interactions between plants and pollinators) and community structure and composition (Hughes 2000, p. 59). In turn, those changes could affect disturbance regimes and other physical processes, such as fire regimes (D'Antonio and Vitousek 1992, entire).

Physiological effects and plant responses

In the recent geologic past—until the last 200 years—CO_2 concentrations were relatively low (Taiz and Zeiger 2010, pp. 257). Therefore, plant species alive today evolved in a low-CO2 environment (Taiz and Zeiger 2010, p. 257). In addition to the C_3 pathway used by most plants, including *Ceanothus ophiochilus*, two photosynthetic pathways evolved in response to low levels of atmospheric CO_2: C_4 photosynthetic carbon fixation (C_4), and Crassulacean acid metabolism (CAM) (Taiz and Zeiger 2010, p. 216). Briefly, these pathways minimize carbon loss by concentrating CO_2 at the site of rubisco (an enzyme), which catalyzes the first step in the carbon fixation pathway. Because *C. ophiochilus* is a C_3 plant, we discuss the impacts of increased atmospheric CO_2 concentration and temperature on the C_3 photosynthetic pathway.

Higher CO_2 concentrations support higher photosynthetic rates (Taiz and Zeiger 2010, pp. 256–257). Because CO_2 availability limits photosynthetic rates for C_3 plants, C_3 plants could benefit from increasing CO_2 concentrations, as long as other resources (i.e., water and nutrients) are not limiting (Taiz and Zeiger 2010, pp. 261–262). In Free Air CO_2 Enrichment (FACE) experiments, open-air fields are artificially enriched with CO_2 gas. In a meta-analysis of 120 FACE studies encompassing 40 species, Ainsworth and Long (2005) reported that elevated CO_2 concentrations resulted in an average 31 percent increase in photosynthetic rate, but that different plant functional groups (i.e., trees, shrubs, grasses, and legumes) responded differently to increased CO_2 (pp. 354–357). They also reported increased plant growth and above-ground biomass production with elevated CO_2, although responses varied depending on the plant species and growing conditions (pp. 358–360). And if water is not limiting, C_3 plants are much more responsive to increased CO_2 than C_4 plants (Ainsworth and Long 2005, p. 354; Taiz and Zeiger 2010, pp. 260–262).

How do plants adapted to arid environments respond to increased atmospheric CO_2? Under elevated CO_2 concentrations, plants close their stomata, which could decrease water loss (Taiz and Zeiger 2010, p. 262). Could elevated CO_2 increase productivity in desert shrubs by reducing water stress while allowing photosynthesis, as suggested by Smith *et al.* (1997)? In a study of three desert shrubs at the Nevada Desert FACE (Mojave Desert), Naumburg *et al.* (2003) found that photosynthetic rates increased within increasing CO_2 concentrations, but that responses to elevated CO_2 were species-specific, and dependent on precipitation (pp. 279–282). Plants grown under conditions of elevated CO_2 took up more carbon in wetter years than in dry years (p. 281), but during dry years seasons, there was no extended period of photosynthetic activity under elevated CO_2 (p. 281) (see also Hamerlynck *et al.* 2000, pp. 430–431). Naumburg *et al.* (2003, p. 283) concluded that due to water limitations, desert shrubs may be less responsive to elevated CO_2 compared with plant species in wetter ecosystems.

Photosynthesis is a process that is sensitive to temperature. A species' optimal temperature for photosynthesis is the temperature at which its photosynthetic rate is highest (Taiz and Zeiger 2010, p. 256). Different species have different optimal temperatures, and even plants of the same species may have different optimal temperatures, depending on the conditions they were grown in (Taiz and Zeiger 2010, p. 256). For example, for some plants in Death Valley, California, the optimal temperature for photosynthesis is 122 degrees F (50 degrees C) (Taiz and Zeiger 2010, p. 256), whereas optimal temperatures are much lower for alpine species. Future climate projections indicate that minimum and maximum temperature will increase in southern California, and extremely hot days are expected to become more frequent (see **Temperature** for further discussion). It is unclear whether increases will occur beyond the optimal temperature for *Ceanothus ophiochilus*, or whether *C. ophiochilus* can acclimate or adapt to temperature increases.

Droughts are projected to become more frequent and intense in southern California. Venturas *et al.* (2016) studied shrub mortality in southern California chaparral during the 2014 drought. They examined shrub species of four life history types, including species that must recruit from seeds (obligate seeders), and species that can reestablish from both underground structures and seeds (facultative seeders) (p. 3). Obligate seeders had greater cavitation resistance (i.e., resistance to loss of water tension), but also had higher mortality during intense drought (pp. 14–17). Increased mortality was likely due to the relatively less extensive root systems of obligate seeders, compared with species that are capable of resprouting after fire (p. 15). Although *Ceanothus ophiochilus* was not included in the study, it may have a similar response to drought as other obligate seeding *Ceanothus*.

In summary, projected changes in future climate in southern California—particularly increasing temperatures caused by increased greenhouse gas concentrations—will likely affect physiological processes of chaparral shrubs. We do not have species-specific information about whether, or how, changing climate may affect *Ceanothus ophiochilus*. Based on other studies of desert and chaparral shrubs, possible physiological responses of *C. ophiochilus* to elevated atmospheric CO_2, increasing temperatures, and more frequent and intense drought are: 1) increasing atmospheric CO_2 could increase carbon uptake and above-ground biomass, particularly during wet years, but increases could be small when water is limiting; 2) increasing temperatures could shift ambient air temperatures outside optimal temperatures for photosynthesis; and 3) more frequent, intense drought could increase *C. ophiochilus* mortality. However, all of these possible responses are highly uncertain.

Range shifts in response to increased temperature

Range shifts in response to climate change have been documented in many species (Thomas 2005, pp. 79–92; Lenoir *et al.* 2008, p. 1768–1770) and modeled in many others (Loarie *et al.* 2008, p. 1; Loarie *et al.* 2009, p. 1052–1054). While some species may be able to shift pole-ward or upslope in response to increasing temperatures, or otherwise expand into previously unsuitable habitat, species with narrow habitat requirements may be limited in their ability to shift their range (Thomas 2005, pp. 82–93; Damschen *et al.* 2012, p. 1123).

For plant species endemic to unusual and/or low nutrient soils (such as serpentine, gypsum, shale, or carbonate; Damschen *et al.* 2012, p. 1123), increasing temperatures may reduce or eliminate the overlap between areas of suitable soils, and areas of suitable climate. If edaphic (soil)-endemic plants are not able to adapt to changing climate in place, adapt to new soils, or disperse to new areas of suitable habitat, populations may decline or be locally extirpated (Thomas 2005, p. 83; Damschen *et al.* 2012, p. 1124). On the other hand, studies in the United Kingdom have found that edaphic-endemic species adapted to harsh soils—for example, carbonate or serpentine—may be less sensitive to precipitation and temperature changes (Grime *et al.* 2000, entire; Grime *et al.* 2008, entire), suggesting increased resiliency to changing climate.

Several studies of serpentine vegetation communities in California have reported that plants on serpentine soils are less sensitive to climatic variation (reviewed in Damschen *et al.* 2012; see also Harrison *et al.* 2015, p. 1018). Compared with communities on more fertile soils, some studies reported that serpentine communities have more stress-tolerant species—with traits such as high water use efficiency and low growth rates—and show less change in community composition with changing climate (Fernandez-Going *et al.* 2012; Harrison *et al.* 2015, p. 1018). However, in a study that resampled serpentine plant communities in southern Oregon and northern California (Damschen *et al.* 2010, p. 3610; resampled sites in Whittaker 1960, entire), researchers found contrary evidence: on both serpentine and the surrounding non-serpentine soils, total herb cover declined dramatically from 1950 to 2007 (p. 3613). Relative cover declined for species endemic to serpentine soils, and for species near the northern latitudinal limit of their range (pp. 3614–3616).

To reconcile these seemingly contradictory results, Harrison *et al.* (2015) reanalyzed the results of Damschen *et al.* (2010) using additional covariates of soil type, overstory cover, and soil texture (p. 1019). They also used specific leaf area (SLA, leaf area divided by dry mass) as a metric to examine vegetation composition shifts (drought-tolerant species have a low SLA) (p. 1019). On non-serpentine soils, community mean SLA significantly declined between 1950 and 2007, but there was no significant change in community SLA on serpentine soils (pp. 1020–1021). These results indicate that a loss of drought-intolerant species occurred on non-serpentine soils, and suggested that serpentine species are more stress-tolerant (p. 1020).

Less community change also occurred in areas with more overstory cover, which lowered understory temperature (p. 1020).

In summary, studies by Grime *et al.* (2000, 2008) on carbonate soils in the United Kingdom, and by numerous authors on serpentine soils in California (see Damschen *et al.* 2012; Harrison *et al.* 2015), have generally supported the hypothesis that plant communities adapted to harsh soils have higher resistance to increasing aridity (i.e., either declining precipitation and/or moisture deficit caused by increasing temperatures) (Harrison *et al.* 2015, p. 1021). Like plant taxa on serpentine substrates, *Ceanothus ophiochilus* has some drought-adapted features, including small leaf size and small status (Boyd *et al.* 1991, p. 37). However, we have no information about whether edaphic-endemic *Ceanothus* on non-serpentine soils in California—including *C. ophiochilus*—are similarly less sensitive to changing climate.

Species distribution modeling can predict species' range shifts with changing climate, using projections of future climate along with information about past or current species ranges. Riordan *et al.* (2018) modeled the mid-century ranges of seven *Ceanothus* in southern California chaparral, using five projections of future climate. Future habitat suitability varied within the genus; some *Ceanothus* (*C. perplexans*) were projected to experience losses of suitable habitat under most scenarios, while habitat for other *Ceanothus* (*C. crassifolius* var. *crassifolius*) was projected to remain stable (p. 23).

Ceanothus ophiochilus is endemic to isolated patches of gabbro and pyroxenite-rich outcrops (Vail Lake), or within a mix of gabbro and sedimentary deposits (Agua Tibia Wilderness) (Boyd and Banks 1995, p. 37). Further study is needed to determine whether suitable habitat is present upslope of current locations; it's possible that the species may be able to move upslope or to a different aspect in response to increased temperatures, and assisted migration may also be an appropriate management strategy. It's also possible that *C. ophiochilus* could adapt to changing climate in place.

Changing disturbance regimes

In addition to directly impacting plant physiological processes, climate change will likely interact with other stressors (nonnative plant introduction and spread, habitat fragmentation, increased fire frequency, and nitrogen deposition) to alter disturbance regimes in southern California chaparral. Two projected changes—increasing temperatures and altered precipitation, including increased drought frequency and intensity—may interact to decrease fuel moisture, increasing the likelihood of fire ignition and spread.

Changing biotic interactions

Shifts in life cycle timing (phenology) have been observed for many species around the world (Root and Hughes 2005, p. 63). Plants are generally expected to advance their phenology (i.e., germinate, flower, and fruit earlier) in response to warming temperatures (Hughes 2000, p. 60; Root and Hughes 2005, p. 61). Phenological shifts can impact biotic interactions between plants and their pollinators, especially if one partner relies on a fixed phenological cue (such as day length) and the other on a changing cue (such as temperature) (Hughes 2000, pp. 59, 61; Root and Hughes 2005, pp. 62–67).

Flowering in plants may occur in response to only internal developmental cues, in response to only environmental cues, or in response to both internal and environmental cues (Taiz and Zeiger 2010, p. 724). Photoperiod (length of day or darkness), vernalization (a period of cold temperature), precipitation, ambient temperature, and light quality may all be important cues for flowering phenology in plants, depending on the species and ecosystem (Root and Hughes 2005, p. 62; Taiz and Zeiger 2010, pp. 725–726). For example, in a study of seven southern California annuals, Slade *et al.* (1975, pp. 209–214) found that germination generally highly correlated with a precipitation event/soil moisture, and later phenological phases (budding, flowering, fruiting) were determined by the time since the previous phase.

In additional to affecting physiology and phenology in plant species, higher temperatures can impact the physiology and phenology of insect pollinators. Soroye *et al.* (2020) compared bumble bee species richness and occupancy between baseline (1901–1970) and recent (2000–2015) time periods, using observational data of 66 bumble bee species from North America and Europe (pp. 1–2). They found that bumble bee species' occupancy and richness were more likely to decline in areas near the warmest part of the range, and increase near the coldest part of the range (pp. 2–4).

Phenological decouplings may have both short-term consequences for individual plant reproduction, and longer-term consequences for genetic diversity and population size. For example, plants not able to self-fertilize, (i.e., plants that are self-incompatible or unable to self-pollinate) would have very low or no reproduction if pollinators were absent, or reduced reproduction if the temporal overlap between flowering and pollinator activity were reduced. And over time, reduced input to the seed bank could reduce plant population size, increasing a plant population's vulnerability to environmental, genetic, and demographic (for dioecious plant species) stochasticity.

Although pollination and seed set have not been closely studied for *Ceanothus ophiochilus*, the species is presumably pollinated by generalist foragers. If phenological mismatches did develop between *C. ophiochilus* and any one of its pollinators, other generalist insects could continue to pollinate *C. ophiochilus*, potentially buffering against a complete loss of pollinator services.

SUMMARY

Future conditions of climate warming—increased atmospheric CO_2 concentration, increased temperature, and more frequent and intense storms and droughts—may interact with other stressors to impact the physiological response, range, biotic interactions, and disturbance regimes of *Ceanothus ophiochilus* individual plants and habitat. Although we have more information about changing climate in southern California, we do not have additional information, or certainty, about the response of *C. ophiochilus* to these changing conditions. Therefore, as in the 2013 5-year review, we continue to consider climate change a rangewide threat to *C. ophiochilus* plants and habitat.