**Title**

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**Abstract**

**Introduction**

* Motivation for the study
  + Importance of demographic information for conservation
  + Of particular importance for rare plants
    - Important to identify life stages most relevant to population growth/persistence—considering *every* life stage
      * Talk about seedbanks here
    - Also important to identify other processes that affect population growth/persistence, and may allow rare populations to persist
* Introduce study species
  + Basic intro
    - *O. coloradesis* is "weakly conserved", and has a "protection status score" of 1.7 out of 10 (Rondeau et al., 2011)—primarily due to lack of conservation of its habitat, and likelihood of development impact (particularly oil and gas)
    - ESA listing rule: (Jennings, 2000)
    - Delisting proposal: (Kurth, 2018)
    - Final desilting rule: (Everson, 2019)
    - 2021 WYNDD monitoring report (Heidel, Tuthill, & Wallace, 2021) (incorporates census data through 2020)
  + Previous work
    - Floyd and Ranker; Burgess; WYNDD monitoring; Soapstone counts?
    - Floyd and Ranker identified size as the more important for lambda than age
* Brief synopsis of what we did

**Methods**

*Species description*

*Oenothera coloradensis*, formerly *Gaura neomexicana spp. coloradensis* (Wagner, Hoch, & Raven, 2007), is an herbaceous, monocarpic perennial plant in the Onagraceae family. Non-reproductive plants consist of a rosette of basal leaves with a fleshy taproot. Flowering typically occurs around four years of age, when plants send up a stalk between 10 and 30 cm tall that bears flowers and fruits. Plants almost always die after flowering. Seeds are contained within small, woody, indehiscent capsules that contain two to five seeds each (Burgess, Hild, & Shaw, 2005). A single adult plant can produce more than 500 capsules. This species does not reproduce vegetatively, although seeds typically germinate near the base of the parent plant, which often results in dense clumps of mature individuals (Heidel et al., 2021). *O. coloradensis* has no known specialist pollinators or seed dispersers.

Previous work established that *O. coloradensis* population growth rate is particularly impacted by recruitment of individuals to the small rosette, or seedling, stage (Floyd & Ranker, 1998). Seedling recruitment increases when non-*O. coloradensis* biomass is removed, indicating that surrounding grasses and forbs outcompete or shade-out seedlings (Munk, Hild, & Whitson, 2002). Previous work also suggests that seedbanks are important for this species, since years of high seedling density are not necessarily preceded by years of high rates of flowering and seed production (Munk et al., 2002). The *O. coloradensis* seedbank has not been studied directly, but a greenhouse seed viability and germination study showed that an average of 58% of seeds produced by a parent plant are viable, and that a viable seed has a 20% mean probability of germinating (Burgess et al., 2005). Neither seed viability nor germination rate changed meaningfully over the five years of the study. These results also showed that two-months of cold-moist stratification triggered germination.

This species primarily occurs in open, frequently disturbed habitats with sub-irrigated, alluvial soils (Jennings, 2000). Populations typically occur within the floodplain of ephemeral or perennial streams, but also exist in wet meadows, drainage bottoms, and spring-fed wetlands (Munk, 1999). *O*. *coloradensis* commonly co-occurs with ﻿*Agrostis stolonifera*, *Pascopyrum smithii*, *Poa pratensis*, *Glycyrrhiza lepidota*, *Iris missouriensis*, *Cirsium flodmanii*, and *Grindelia squarrosa* (Jennings, 2000; Munk et al., 2002). Encroachment of woody shrubs such as *Salix exigua* has been correlated with declining numbers in some populations (Heidel et al., 2021). Relatively frequent disturbance such as flooding that reduces growth of both woody and herbaceous species and removes litter is important for this species, especially for successful seedling recruitment (Burgess, 2003; Jennings, 2000).

All historical and extant known *O. coloradensis* populations lie within a ﻿17,000 acre area that includes southeast Wyoming, northern Colorado, and a small part of southwest Nebraska. Range-wide survey efforts between 1984 and 1986 identified more than 20 populations. The largest population on Federal land occurs on the F. E. Warren Airforce Base near Cheyenne, WY. The Wyoming Natural Diversity Database (WYNDD) began a base-wide census of reproductive individuals in this population in 1986, and has repeated this census annually since 1988 (Heidel et al., 2021). The Soapstone Prairie Natural Area, a public property owned by the city of Fort Collins, CO, has the largest documented number of *O. coloradensis* individuals, but this population has not been routinely monitored. The first estimate of species size after its full geographic range was identified occurred in 1998, when it was approximated that the entire species consisted of 47,300 to 50,300 reproductive individuals (Jennings, 2000). Although an older estimate of total species numbers or geographic range does not exist to serve as a reference, decline in a majority of the known populations between the mid-1980s and 2000 lead the U.S. Fish and Wildlife Service (USFWS) to designate *O. coloradensis* as a “threatened” species protected under the Endangered Species Act (Jennings, 2000). Although this species appears to be naturally rare, mangers were concerned that, without protection, *O. coloradensis* had the potential for extinction because of habitat loss due to ranching, natural resource extraction, and shrub encroachment resulting from altered disturbance regimes.

*Demographic Data Collection*

We collected demographic data

* Site descriptions
* Timeline of data collection
* Types of data collected
  + Demographic data
  + Environmental co-variates

*Integral Projection Model*

* Types of IPMs (deterministic; D-dependence; D-independence; w/ environmental covariates)
* For each model:
  + Vital rate models
    - Model validation procedure for each vital rate model
  + Derivation of seedbank parameters
  + IPM parameters

**Results**

**Discussion**

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\*\* change the Rondeau and Heidel citations to include the ‘Prepared for…” statements \*\* also maybe change the italicization of the species name, if required