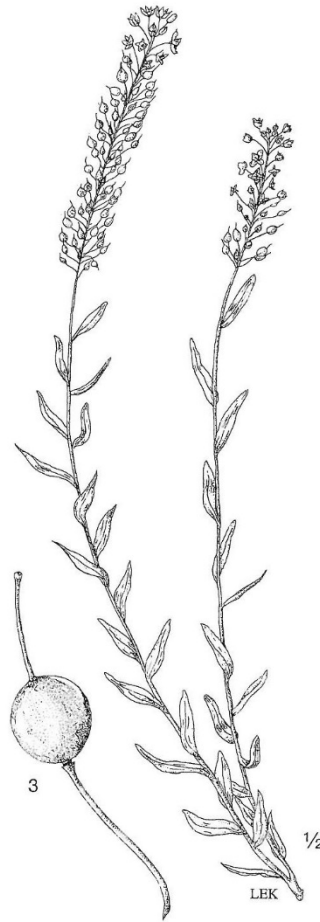# Species Status Assessment Report
Short's Bladderpod (*Physaria globosa*)
Version 1.1 August 2020

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U.S. Fish and Wildlife Service
Interior Region 2, South Atlantic-Gulf
Atlanta, Georgia

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Summary of Version Updates:

The changes from version 1.0 (December 2017) to 1.1 (August 2020) are minor and do not change the SSA analysis framework. These changes include the following:

1. New information was added to the following subsections of section 2.3 Individual Ecology:

    a. 2.3.2.3 Pollination

    b. 2.3.2.4 Reproductive Output

    c. 2.3.3.2 Soil Seed Bank, Germination, and Dormancy

2. New information was added to subsection 2.4.2 Habitat, in section 2.4 Population-level Ecology.

3. Chapter 3 Analysis of Historical and Current Condition has been updated to incorporate current data from Natural Heritage Programs in Indiana, Kentucky, and Tennessee and to include more current information on potential development of a commuter rail line within the range of Short's bladderpod. We also changed the number of counties where extant populations are currently found to 12, which was erroneously reported as 13 in version 1.0.

Executive Summary

This report summarizes the results of a species status assessment (SSA) completed for Short's bladderpod (*Physaria globosa*), to assess the species' overall viability and predict future status in response to alternative conservation scenarios. Short's bladderpod was federally listed as endangered on August 1, 2014 (79 FR 44712) and is also listed as endangered by the three states from which occurrences are known: Indiana, Kentucky, and Tennessee. The species has a disjunct distribution, with populations known historically from Posey County, Indiana; Bourbon, Clark, Fayette, Franklin, Jessamine, Madison, Mercer, Nelson, Powell, Scott and Woodford Counties, Kentucky; and Cheatham, Davidson, Dickson, Jackson, Maury, Montgomery, Smith, Trousdale, and Williamson Counties, Tennessee.

To assess the species' viability, we used the three conservation biology principles of resiliency, representation, and redundancy. Specifically, we identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described the beneficial and risk factors influencing Short's bladderpod viability. We evaluated the changes in representation, resiliency, and redundancy from historical to the current time, and forecasted changes into the future based on a range of conservation scenarios.

Short's bladderpod is a biennial or perennial that typically flowers and produces seed during the months of March through June. Timing of seed germination is not currently known, but it is possible that seeds could germinate in the fall and form rosettes over winter, germinate in spring when conditions become favorable, or exhibit either phenology depending upon the dormancy status of individual seeds and variation in seasonal climatic conditions. Fitness of Short's bladderpod individuals is dependent on appropriate temperature, soil moisture and nutrients, and light regimes for seed germination; growth of seedlings, rosettes, and adults; and reproduction. Availability of mate-compatible genotypes and abundance of pollinators are critical factors for production of viable seed. Healthy genetic and demographic structure are needed for populations to be resilient to environmental change and variation. Maintaining stable or growing Short's bladderpod populations requires habitats with low levels of shading from overstory and midstory vegetation, resulting from a combination of disturbances to create canopy openings and shallow soils limiting soil moisture available for growth of woody plants. Extensive alteration of soil structure should be minimized to avoid loss of the soil seed bank and maintain sites for ground-nesting pollinators, as should invasion by non-native plants to reduce sources of undesirable shading or competition.

We evaluated the change in resiliency, representation, and redundancy from the past until the present, and projected the anticipated future states of these conditions. To forecast the biological condition into the future, we developed three alternative scenarios, which vary with respect to combinations of conservation interventions that could be undertaken to reduce effects of stressors and the scale at which they would be implemented. We predicted outcomes of these scenarios, with respect to changes in the resiliency, representation, and redundancy of Short's bladderpod populations, based on expected responses of individual populations to conservation efforts.

Since 1991, the number of extant Short's bladderpod populations has increased from 25 to 33. In 1992, 18 of the populations consisted of less than 100 individuals, whereas this is true for 28 of the currently extant populations. One or more threats, including right-of-way maintenance, overstory shading, invasive species, and small population size affect most populations. The historical and current distributions of Short's bladderpod are characterized primarily by populations of low resiliency, owing to small population sizes and presence of threats to the species, its habitat, or both. The vulnerability of small populations is borne out by the turnover in occurrences of the species between 1992 and present day, resulting in the loss of at least 8 occurrences during that time period. With regard to the species' overall resilience, the discovery of additional, albeit small, populations in Tennessee since 1992 have potentially offset these losses.

We used trends in number of EPA Level IV Ecoregions (ecoregions), states, and counties occupied by the species as measures of representation. The species representation has changed between 1992 and 2019 with respect to the ecoregions and counties where it occurs. The species is still considered extant in Kentucky, Indiana, and Tennessee; though, no plants were observed during 2018 and 2019 at the lone occurrence in Indiana. The species' representation has increased in terms of numbers of counties occupied, from 10 in 1992, to 12 in 2019; despite extirpation from two counties during that time span. In Kentucky, the species is no longer extant in Bourbon or Scott counties, but is now present in Madison and Woodford counties. In Tennessee, the species was discovered in Dickson and Jackson counties after 1992.

We evaluated redundancy of Short's bladderpod by examining trends in total number of occurrences and number of occurrences with ≥100 individuals per ecoregion, state, and county. The one Indiana occurrence, located in the Wabash-Ohio Bottomlands ecoregion, has apparently decreased in number from an estimated hundreds-to-thousands of plants in 1992 to a few hundred plants observed during 2020. No plants were observed during site visits in 2018 and 2019, due to prolonged inundation of the site during both years. The observation of a few hundred plants in 2020 marks the first time that more than 100 plants have been observed at this site since 2012.

As of 1992, there were 13 Short's bladderpod occurrences in Kentucky, with 10 of those occurrences in Franklin County alone. These occurrences were distributed among the Hills of the Bluegrass (8), Inner Bluegrass (4), and Outer Bluegrass (1) ecoregions. Only two occurrences consisting of at least 100 individuals were known from Kentucky, one each in Bourbon (Outer Bluegrass) and Franklin (Inner Bluegrass) Counties. There are now 11 occurrences in Kentucky, reduced to the Hills of the Bluegrass (8) and Inner Bluegrass (3) ecoregions, with the greatest concentration still in Franklin County. One of the Franklin County occurrences has been established via introduction, with seeds first introduced to the site in 2014. Recent data indicated that there are no Kentucky populations where more than 100 individuals were present at last observation. The Bourbon County occurrence, where 118 Short's bladderpod were present in 1992, and a smaller occurrence in Scott County have been extirpated.

In Tennessee, there were five occurrences located in the Western Highland Rim ecoregion and six in the Outer Nashville Basin as of 1992. Cheatham was the only Tennessee county with more than three occurrences in 1992. Two occurrences each in the Western Highland Rim and Outer Nashville Basin ecoregions consisted of at least 100 individuals - one each in Cheatham, Davidson, and Trousdale counties and one at the Cheatham/Davidson county boundary.

Currently there are 10 occurrences located in the Western Highland Rim ecoregion and 11 in the Outer Nashville Basin. Cheatham County still has the greatest number of occurrences in Tennessee, up to six from the four that were known in 1992. There are 3 occurrences with at least 100 individuals in the Western Highland Rim ecoregion and 1 in the Outer Nashville Basin.

To characterize expected future conditions for Short's bladderpod, we examined risk factors identified in the SSA to construct alternative scenarios, which vary with respect to combinations of conservation interventions that could be undertaken to reduce effects of stressors and the scale at which they would be implemented. The specific interventions assessed in the scenarios are developing conservation agreements/strategies, protecting populations on private lands, controlling invasive plants, reducing overstory shading, and augmenting populations. Anticipated outcomes, in terms of abundance and distribution of populations consisting of more than 100 individuals, in response to the three conservation scenarios we considered are summarized in the table below.

State	EPA Level IV Ecoregion	County	2020 Status		Number of Occurrences ≥ 100 individuals		
			Number of Occurrences	Number of Occurrences ≥ 100 Individuals	Scenario 1	Scenario 2	Scenario 3
Indiana	Wabash-Ohio Bottomlands	Posey	1	1	1	1	1
Kentucky	Inner Bluegrass	Clark	1	0	0	0	1
		Franklin	1	0	0	1	1
		Woodford	1	0	0	0	1
		Total	3	0	0	1	3
	Hills of the Bluegrass	Franklin	7	0	1	4	6
		Madison	1	0	0	0	1
		Total	8	0	1	4	7
Tennessee	Western Highland Rim	Cheatham	5	2	4	4	5
		Davidson/Cheatham	1	1	1	1	1
		Dickson	1	0	1	1	1
		Montgomery	3	0	3	3	3
		Total	10	3	9	9	10
	Outer Nashville Basin	Davidson	3	1	3	3	3
		Jackson	3	0	3	3	3
		Smith	2	0	2	2	2
		Trousdale	3	0	3	3	3
		Total	11	1	11	11	11
Overall Total			33	5	22	26	32

Table of Contents

1 Introduction

Short's bladderpod (*Physaria globosa*) was federally listed as endangered on August 1, 2014 (79 FR 44712) and is also listed as endangered by the three states from which occurrences are known: Indiana, Kentucky, and Tennessee. Listing under the Endangered Species Act of 1973, as amended (Act), triggers certain requirements of the Service, including preparation of a species recovery plan. Recovery plans include: descriptions of actions that may be necessary for conservation and survival of the species; objective, measurable criteria for determining when the species could be removed from the list; and an estimate of the time required and cost to carry out the actions needed to recover the species. The Act also requires other Federal agencies to (1) utilize their authorities to carry out conservation programs for the conservation of threatened and endangered species and (2) to consult with the Service to ensure that actions they undertake, permit, or fund do not jeopardize the continued existence of listed species or adversely modify designated critical habitat. Fulfilling these responsibilities requires using the best scientific and commercial data available. This Species Status Assessment (SSA) provides the scientific grounding for decisions made by the Service and others in efforts to conserve Short's bladderpod.

Our approach for assessing Short's bladderpod viability involved three stages. In Stage 1, we described the species' ecology in terms of its resiliency, redundancy, and representation (3Rs, as adapted from Shaffer and Stein 2000, entire). Specifically, we identified the ecological requirements for survival and reproduction at the individual, population, and species levels. In Stage 2, we determined the baseline condition of the species using the ecological requirements identified in Stage 1. That is, we assessed the species' historical and current condition in relation to the 3Rs and identified past and ongoing factors (beneficial and risk factors) that led to the species' current condition. In Stage 3, using the baseline conditions established in Stage 2 and the predictions for future risk and beneficial factors, we projected the likely future conservation scenarios of Short's bladderpod.

The SSA assesses the ability of Short's bladderpod to maintain populations over time. In doing so, this SSA provides an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. Viability is the ability to sustain populations over time; to do this, a species must have a sufficient number and distribution of healthy populations to withstand changes in its biological and physical environment, environmental stochasticity, and catastrophic or transient perturbations. Viability in this context is not expressed in binary terms, *i.e.*, viable or not viable; rather, there are degrees of viability – less to more viable or low to high viability. In this document, we consider what Short's bladderpod needs to maintain viability by characterizing the historical, current, and potential future status of the species in terms of the 3Rs.

1.1 Resiliency

Resiliency is the ability to sustain populations in the face of environmental variation and transient perturbations. Environmental variation includes normal year-to-year variation in rainfall and temperatures, as well as unseasonal weather events. Perturbations are stochastic events such as fire, flooding, and storms. Simply stated, resiliency is having the means to recover from "bad years" and disturbances. To be resilient, a species must have healthy

populations; that is, populations that are able to sustain themselves through good and bad years. The healthier the populations and the greater number of healthy populations, the more resiliency a species possesses. For many species, resiliency is also affected by the degree of connectivity among populations and the diversity of ecological niches occupied. Connectivity among populations may improve the genetic health of individuals within a population and bolster a population's ability to recover from disturbances via rescue effect (immigration). Diversity of climate niches improves a species' resiliency by guarding against disturbances and perturbations affecting all populations similarly (*i.e.*, decreases the chance of all populations experiencing bad years simultaneously or to the same extent).

1.2 Representation

Representation is the range of variation found in a species, and this variation – or adaptive diversity – is the source of a species' ability to adapt to near and long-term changes in the environment. Maintaining adaptive diversity includes conserving both the ecological and genetic diversity of a species. By maintaining these two sources of adaptive diversity across a species' range, the more responsive and adaptive to change – and therefore viable – a species will be. Ecological diversity, or phenotypic variation, is the physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of alleles within and among populations, especially rare or unique alleles found in few populations.

In addition to preserving the breadth of adaptive diversity, maintaining evolutionary capacity requires maintaining the evolutionary processes that drive evolution; namely, gene flow, genetic drift, and natural selection. Gene flow is expressed through the physical transfer of genes or alleles from one population to another through immigration and breeding. The presence or absence of gene flow can directly affect the size of the gene pool available. Gene flow will generally increase genetic variation within populations by bringing in new alleles from elsewhere but decrease genetic variation among populations by mixing their gene pools (Allendorf and Luikart 2007, p. 206). Genetic drift is the change in the frequency of alleles in a population due to random, stochastic events. Genetic drift always occurs but is more likely to negatively affect populations that have a smaller effective population size (Ne) and populations that are geographically spread and isolated from one another. Natural selection is the process by which heritable traits can become more (selected for) or less (not selected for) common in a population based on the reproductive success of an individual with those traits. Natural selection influences the gene pool by determining which alleles are perpetuated in particular environments. This selection process operates on populations to generate unique alleles and allelic frequencies, which reflect specific ecological, physiological, and behavioral adaptations for survival in different environments.

1.3 Redundancy

Redundancy protects species against the unpredictable and highly consequential events for which adaptation is unlikely, allowing them to withstand catastrophic events. In short, it is about spreading the risk. Redundancy is best achieved by having multiple populations widely distributed across a species' range. Having multiple populations reduces the likelihood that all populations are affected simultaneously, while having widely distributed populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event. Given

sufficient redundancy, single or multiple catastrophic events are unlikely to cause the extinction of a species. Thus, the greater redundancy a species has, the more viable it will be. Furthermore, the more populations and the more diverse or widespread that these populations are, the more likely it is that the adaptive diversity of the species will be preserved. Having multiple populations distributed across the range of the species will help preserve the breadth of adaptive diversity, and hence the evolutionary flexibility of the species.

2   Species Ecology

In this section, we discuss information regarding taxonomy, species description, life history, reproductive biology, seed ecology, genetics, and habitat. This information is used to describe the ecological requirements for survival and recovery for Short's bladderpod at the individual, population, and species levels; characterizing conditions that would provide sufficient resiliency, representation, and redundancy to promote the species' viability.

2.1   Taxonomic Background

A member of the mustard family (Brassicaceae), Short's bladderpod was first described as *Vesicaria globosa* by Desvaux (1814, p. 184). Because of several distinctive characters, Watson (1888, pp. 249-250) proposed that the American species of the genus *Vesicaria* be placed in the genus *Lesquerella*. This treatment was recognized as valid, until Al-Shehbaz and O'Kane (2002, entire) united most of the genus *Lesquerella* with the genus *Physaria*. This determination was supported by molecular, morphological, cytological, biogeographic, and ecological lines of evidence (Al-Shehbaz and O'Kane 2002, entire). Flora of North America recognizes this change, using the scientific name *Physaria globosa* for Short's bladderpod (O'Kane 2010, p. 639).

The holotype for *Vesicaria globosa* is located at the Herbarium of the Museum National d'Histoire Naturelle in Paris, France (P) (Rollins and Shaw 1973, p. 166). Interestingly, the label on the type specimen reads as *Vesicaria globulosa* rather than *V. globosa*, as published by Desvaux (Payson 1921, p. 203). The holotype labels states ""Cette plante croit dans les lieux arides de l'Amérique septentrionale" (Al-Shehbaz and O'Kane 2002, p. 323), which translates literally to "This plant grows in dry places of Northern America." No collector is given for the holotype, though a fragment believed to be from the type, located in the Gray herbarium at Harvard, is accompanied by a note from Asa Gray suggesting that Constantine Rafinesque may have been the collector (Rollins 1952, p. 191). Rollins and Shaw (1973, p. 166) also suggested that the collector may have been André Michaux. Who actually collected the holotype specimen is not known with certainty.

The common name Short's bladderpod is derived from a collection by Dr. Charles Wilkens Short, a preeminent authority on the Kentucky Flora, in 1835 from the banks of Elkhorn Creek near Frankfort, Kentucky (Rollins and Shaw 1973, p. 166). Short's collection was described as a new species, *Vesicaria shortii*, by Torrey and Gray (1838, p. 102), who were unaware of the pre-existing description of the taxon by Desvaux (1814, p. 184). In *Catalogue of the Native Phaenogamous Plants and Ferns of Kentucky*, Short (1833, p. 339) commented "This very rare

plant, of which we have only met with two imperfect specimens, on Elkhorn creek between Lexington and Frankfort, is considered by Dr. Torrey as a new species."

The genus *Physaria*, as presently circumscribed, includes 88 species (O'Kane 2010, entire; O'Kane, pers. comm., November 2015), predominantly distributed in arid regions of the western United States and northern Mexico (Al-Shehbaz and O'Kane 2002, p. 319). The range of several taxa extends into Canada, with one taxon, *P. arctica*, distributed from Greenland and Northern Canada to Alaska and Northeastern Russia (Al-Shehbaz and O'Kane 2002, p. 319). Six species of *Physaria* are also known from South America, specifically Argentina and adjacent portions of Bolivia and Uruguay, and are believed to have originated from a single North American ancestor (O'Kane and Al-Shehbaz 2004, entire, Al-Shehbaz and Prina 2009, entire). Rarity and restricted distributions are commonplace within the genus *Physaria*, including 29 species with global ranks of Critically Imperiled (G1) or Imperiled (G2) (NatureServe 2015), and four listed as threatened or endangered by the USFWS.

Within the genus *Physaria*, and earlier treatments of *Lesquerella*, *P. globosa* has long been recognized as a geographically and evolutionarily distinct taxon. Payson, in his 1921 monograph of the genus *Lesquerella*, commented that "*L. globosa* is apparently without close relatives in the genus and one is at a loss to know with which group of species to ally it." In a subsequent treatment of the genus *Lesquerella*, Rollins and Shaw (1973, p. 168) commented that "*Lesquerella globosa* clearly is not closely related to the auriculate-leaved species of the same general geographic region." In addition to this morphological distinction, the other southeastern members of the former genus *Lesquerella* are all annuals (O'Kane and Al-Shehbaz 2002, p. 379), whereas *P. globosa* exhibits a biennial or perennial life history (Rollins and Shaw 1973, p. 167). Subsequently, when Shehbaz and O'Kane (2002, entire) united most species of *Lesquerella* with the genus *Physaria*, auriculate-leaved species of *Lesquerella* were segregated in the new genus *Paysonia* based on morphological, genetic, and ecological evidence (O'Kane and Al-Shehbaz 2002, pp. 379-380). In light of this clear separation from other southeastern species of the now defunct genus *Lesquerella*, *P. globosa* is geographically isolated from its congeners.

2.2 Species Description

Short's bladderpod is in the field from other yellow-flowering mustards with a shared distribution based on dense pubescence (fine hairs) that gives the leaves a gray-green appearance, the small pubescent siliques (pods) born on straight pedicels (stems that attach single flowers to the larger flowering structure), and stems that are typically (though not always) branching to give the plant a low, sprawling, bushy appearance disinguish (Rollins and Shaw 1973, pp. 166-169, Shea 1993, p. 5).

The following technical description of Short's bladderpod is based on Flora of North America (O'Kane 2010, p. 639), Gleason and Cronquist (1991, p. 187), and Krosnick *et al.* (in prep). Short's bladderpod is an upright biennial or perennial (lives for 2 years or longer) with several stems, some branched at the base, reaching heights up to 50 centimeters (cm) (20 inches (in.)), and which are leafy to the base of the inflorescence (a group or cluster of flowers arranged on a stem that is composed of a main branch or a complicated arrangement of branches). The basal leaves, borne on short petioles (stalks) are 2.5 to 5 cm (1 to 2 in.) in length and 0.5 to 1.5 cm (0.2 to 0.6 in.) wide, obovate (egg-shaped and flat, with the narrow end attached to the stalk) or oblanceolate (with the widest portion of the leaf blade beyond the middle) in shape, with a

smooth or slightly wavy margin, and gray-green in color due to a layer of dense hairs. Leaves are gradually reduced in size and petiole length higher up the stem. Numerous flowers are borne on a heterothetic compound raceme, with a rachis consisting of both primary (vertical) and secondary (lateral) axes, each of which produces an indeterminate raceme (elongate, spike-shaped inflorescence to which individual flowers are attached by slender pedicels, or stalks, which in Short's bladderpod are longer than the flowers). The yellow flowers are composed of four spoon-shaped petals, 0.4 to 0.7 cm (0.16 to 0.28 in.) long, with a nectary at the base of each petal. The fruit is globose in shape and lightly beset with stellate (star-shaped) hairs, but becoming smooth with time, and typically contains one to four seeds.

2.3   Individual-level Ecology

2.3.1   Life History

Cranfill *et al*. (1985, p. 196) remarked that very little information had been published on the ecology of Short's bladderpod, an assessment that remains valid. Research is needed to definitively address the longevity of the species, though it appears that both biennial and perennial life-history strategies are expressed by individuals and/or populations. Species in the genus *Physaria* are typically perennial (O'Kane and Al-Shehbaz 2002, p. 379), including some species described as long-lived perennials (e.g. *P. scrotiformis* (O'Kane 2007, p. 376), *P. eriocarpa* (Grady and O'Kane 2007, p. 185)). Biennial and annual species are less common in the genus and are thought to have arisen through derivation from perennial ancestors (O'Kane and Al-Shehbaz 2002, p. 379). Based on morphological characteristics, Rollins and Shaw (1973, p. 168) hypothesized that *P. globosa* evolved from a species similar to *P. ludoviciana*, which is a perennial (O'Kane 2010, p. 649).

The first monograph of *Lesquerella* (Payson 1921, p. 202), described Short's bladderpod as biennial or perennial, though the subsequent monograph by Rollins and Shaw (1973, p. 167) only described the species as perennial. Gleason and Cronquist (1991, p. 187) likewise described the species solely as a perennial. However, Shea (1993, p. 5) described the species as strictly biennial, apparently based on communication with Jerry and Carol Baskin of the University of Kentucky. Jerry Baskin also stated that Short's bladderpod is biennial, in an archived letter to George Rogers, a researcher at the Missouri Botanical Garden (MBG) (Baskin, pers. comm., November 1988). The recent Flora of North America treatment for Short's bladderpod (O'Kane 2010, p. 639) treats the species as a biennial or perennial.

Short's bladderpod germinants produced from a seed germination experiment (Albrecht and Long, unpublished data, discussed below) were potted, vernalized (exposed to prolonged cold temperatures) over the 2013-2014 winter in an unheated hoop house, and subsequently flowered in the spring of 2014. These plants were maintained outdoors in pots through the 2014 growing season, and the surviving individuals were again vernalized in an unheated hoop house over the 2014-2015 winter. These plants flowered again in the spring of 2015, illustrating that Short's bladderpod can be both perennial and polycarpic (capable of more than one reproductive event), an assertion substantiated by photographic evidence of fresh growth and a new inflorescence arising from a withered, woody stem that retained the dried inflorescence from the previous year. These findings are consistent with anecdotal field observations by heritage botanists with the Tennessee Department of Environment and Conservation (TDEC) that some plants develop a

somewhat woody habit and flower in multiple years (Bishop and Fleming, pers. comm., May 2015.).

The above observation contrasts with those of unpublished experiments conducted by Jerry Baskins (pers. comm., November 1988), who concluded that Short's bladderpod is biennial and monocarpic (dies after a single reproductive event). Baskin's assertion is consistent with field observations during recent surveys by the Office of Kentucky Nature Preserves (OKNP, formerly Kentucky State Nature Preserves Commission (KSNPC); Littlefield, pers. comm., May 2015) that Kentucky populations generally consist entirely of either seedlings or reproductive individuals in a given year, indicating a biennial life history. These field observations are further substantiated by a small-scale plot study (KSNPC 2015) at Rockcress Hills State Nature Preserve (Kentucky EO number 22), which lies within the Kentucky River designated critical habitat unit (Unit #15; 79 FR 51035; August 26, 2014). For each plot in this study, Littlefield (KSNPC 2015, p. 2) observed only seedlings in 2011, only adults in 2012, no plants in 2013, and only seedlings in 2014, suggesting a biennial life history.

These preliminary experiments and field observations suggest that the longevity of Short's bladderpod is variable, underscoring the need for further research. It is possible that this species acts as a facultative biennial or perennial in response to local climatic and habitat conditions. Alternatively, given the certain lack of gene flow between the Cumberland River populations and those near the Kentucky River, there may be a genetic basis for potential differences in longevity among these regions. Thus, future research should aim to more thoroughly quantify longevity within and among natural populations and regions, while also employing common garden experiments to further examine potential differences in longevity among individuals and/or populations. Based on observations of an apparent biennial life history in at least some populations, we consider the generation length to be two years – i.e., the time between seed germination and next generation recruitment into the population would be a minimum of two years.

2.3.2   *Reproductive Biology*

Local habitat factors such as canopy cover (Dahlgren *et al*. 2007, pp. 1572-1573) and climatic factors such as temperature and precipitation (Inouye *et al*. 2003, pp. 906-910, Young *et al*. 2004, entire) can influence reproductive output in plants. Research is needed to determine how reproductive output for Short's bladderpod is influenced by environmental factors such as light availability, soil moisture and nutrients, temperature, and precipitation. In addition, it is unknown how seed production is influenced by the species' mating system, the availability of suitable mates, and the role of pollinators in facilitating gene exchange. Knowledge of these processes and aspects of seed ecology discussed below would greatly increase understanding of factors influencing individual fecundity and population growth rates for the species.

2.3.2.1   Phenology

Short's bladderpod flowers from March to as late as June (Rollins and Shaw 1973, p. 167, O'Kane 2010, p. 639, Thacker *et al.* 2019, p. 35), but predominantly during April and May (Gleason and Cronquist 1991, p. 17, Shea 1993, p. 20). Heath Thacker (pers. comm., July 2017) observed plants in a TN population still flowering on July 21, 2017. Seed maturation occurs throughout June, as shown by the range of collection dates for the Missouri Botanical Garden

seedbank (www.livingcollections.org) over two decades. Fruit dehiscence is initiated when plants begin to senesce, typically by late June to beginning of July (Littlefield, pers. comm., November 20, 2017, Thacker *et al.* 2019, p. 32). However, timing of flowering and seed maturation for this species is asynchronous among and within racemes, individual plants, and populations (pers. obs.). Flowering time for plants can vary in response to local habitat conditions and seasonal variation in temperature and precipitation (Inouye *et al.* 2003, pp. 906-910, Dahlgren *et al.* 2007, pp. 1572-1573). How duration and timing of flowering and fruit development in this species are influenced by variation in temperature and precipitation among years is not known.

Short's bladderpod forms an elongated and indeterminate compound raceme that is acropetal (flower and fruit formation is temporally advanced at the lower end of the raceme). It is possible for an individual raceme to contain mature fruits at the base, with a progression from immature fruits, to flowers, to immature buds towards the elongating end of the raceme (Thacker *et al.* 2019, p. 30). The following details on floral phenology in Short's bladderpod are based on observations reported by Thacker *et al.* (2019, p. 32) from a single population of Short's bladderpod located near Hartsville, Tennessee. On the day of anthesis, mature floral buds first opened by approximately 8:30 am, at which time the flowers were functionally male, and stigmas became receptive within one hour. Individual flowers remained functional no longer than three days, and ovaries began visibly inflating within fourteen days of successful fertilization.

Variation in seed maturation is an important consideration for seed banking efforts of *Physaria* species. Grant *et al.* (2012, p. 74) found that the greater maturity of fruits collected from lower portions of *P. ludoviciana* racemes yielded significantly increased seed germination relative to less mature fruits collected from upper portions of racemes, which underscores the importance of collecting fully mature fruits when seed banking *Physaria* species. Aborted capsules were frequently observed on Short's bladderpod plants, especially in the lower third of racemes (Thacker *et al.* 2019, p. 35), indicating that seed collecting would likely be most effective late in maturation of infructescenses.

2.3.2.2   Mating System

Both self-compatibility and self-incompatibility have been documented for members of the genus *Physaria* (Rollins and Shaw 1973, p. 6), and the molecular mechanisms underlying self-recognition between pollen and stigma and subsequent pollen rejection have been well studied in the Brassicaceae (Takayama and Isogai 2005, pp. 468-474). Dr. Carol Baskin (Professor, University of Kentucky, pers. comm., December 2012) concluded that Short's bladderpod is likely self-incompatible based on lack of seed production from plants in a greenhouse where pollinators were absent. Results of preliminary *ex situ* controlled crosses with cultivated Short's bladderpod plants indicate that self-incompatibility mechanisms exist in the species (Krosnick *et al.* in prep). Self-incompatibility has been reported in other *Physaria* species (Bateman 1955, p. 64, Delph 1986, p. 471, Mitchell 1997, p. 1679, Edens-Meier *et al.* 2011, pp. 291-292, Tepedino *et al.* 2012, p. 142), including *P. ludoviciana* (Claerbout *et al.* 2007, p. 134), a geographically proximate congener to which Short's bladderpod may be closely related (Rollins and Shaw 1973, p. 168).

In self-incompatible plants of the Brassicaceae family, when pollen and stigma share haplotypes at the S-locus (self-incompatibility locus, i.e., the position on a chromosome occupied by the self-incompatibility gene complex), pollen tube development is disrupted on the stigma of the female reproductive system (Takayama and Isogai 2005, p. 469). The stigma is the receptive structure of the female reproductive system in plants, which also includes the style and ovary, on which pollen grains germinate and begin development of the pollen tube. Pollen tube formation is necessary for fertilization of the ovary and subsequent seed production to occur. Further research is needed to conclusively determine whether Short's bladderpod is self-compatible and, if it is not, to describe the underlying mechanism preventing self-compatibility and identify populations in which an insufficient number of compatible mates are present to support reproduction of viable progeny and population growth.

2.3.2.3   Pollination

Rollins and Shaw (1973, p. 6) repeatedly observed bees and flies visiting flowers of congeners to Short's bladderpod. *Andrena* sp. (mining bees) were photographed visiting flowers at a Tennessee occurrence in 2015 (pers. obs.; identification by Mike Arduser, Missouri Department of Conservation), but their relative importance for pollination of Short's bladderpod cannot be inferred from coincidental observation. In a study of pollinators at one Tennessee site, two species of dipterans (flies; *Nemotelus bruesii*, *Toxomerus geminatus*) and four species of hymenopterans (bees; *Lasioglossum illinoense*, *L. versatum*, *Halictus ligatus*, *Augochlorella striata*), from the family Halictidae, were determined to be effective pollinators for Short's bladderpod (Thacker *et. al.* 2019, pp. 34-36). Available data indicate that the four species of hymenoptera (Pickering 2009) and *T. geminatus* (Hilty 2015) are generalist foragers. Data on host plants for *N. bruesii* are not available. No significant differences were found among average pollen loads of these six pollinators. However, because of greater visitation frequency, the two fly species were judged more important pollinators than the bee species (Thacker *et. al.* 2019, pp. 32-34), in contrast to studies of some congeners to Short's bladderpod.

The majority of floral foragers observed visiting *Physaria filiformis* (Missouri bladderpod) were true bees representing five families, with greater than 50 percent from the family Halictidae. The families Apidae and Andrenidae also were common among bee pollinators of this species, the most dependable and frequent of which were ground-nesters. Several flies of the family Syrphidae also carried Missouri bladderpod pollen (Edens-Meier *et al.* 2011, p. 293). Tepedino *et al*. (2012, pp. 143-144) found that native ground-nesting bees from the families Andrenidae and Halictidae were the most reliable pollinators visiting flowers of three *Physaria* species, but they reported fewer numbers of pollen-carrying flies from the families Tachinidae and Conopidae. They estimated that maximum flight distance ranged from 100 to 1400 meters (m) (330 to 4593 feet (ft)) for the Andrenids and 40 to 100 m (130 to 330 ft) for the Halictid bees they collected. Assuming similar flight distances for the Halictid bees observed as pollinators for Short's bladderpod, gene flow among populations via pollen transfer could be a low frequency event.

We found little data to describe habitat affinities of the pollinators of *P. globosa* listed above. A study examining how forest structure affected bee diversity and abundance in forests of central Georgia determined that *L. illinoense* was an indicator species of recently harvested pine stands and also documented collections of *H. ligatus* only from open-canopied sites or clearcuts (Hanula *et al.* 2015, pp. 146-149). These results indicate the importance of open habitats for

these species and, potentially, resilience to soil disturbances that could have resulted from recent timber harvests. Multiple studies from the eastern United States indicate that open habitats in otherwise forested landscapes support greater numbers of bees (Hymenoptera) than sites with closed canopies (Campbell *et al.* 2007, p. 396, Grundel *et al.* 2010, p. 1683, Hanula *et al.* 2015, p. 146). One of these studies indicated this was also true for beetles (Coleoptera) and flies (Diptera), with *Toxomerus geminatus* being the most abundant dipteran species captured (Campbell *et al.* 2007, pp. 396-400). Grundel *et al.* (2010, p. 1683) captured significantly higher percentages of soil nesting bees in open habitats and woodlands. Bees of the Halictidae were found to be most abundant in areas treated with mechanical (chainsaw felling/sectioning and understory limbing) and dormant season burns, compared to controls or mechanical or burn treatments applied independently (Campbell 2007, p. 395).

Studies are needed to characterize variation in species serving as effective pollinators across the range of Short's bladderpod and across years in response to environmental variation. Combined with information on effects of light availability, temperature, and precipitation on timing and rates of flower production, these data could be used to estimate potential effects of predicted environmental changes on rates of reproductive output in Short's bladderpod.

2.3.2.4   Reproductive Output

A preliminary investigation of reproductive output conducted in a Short's bladderpod population near Hartsville, Tennessee, during 2016, documented population life history traits related to fecundity and examined the potential influence of irradiance and soil depth on these traits (Krosnick *et al*. in prep). Flower production per individual in this population ranged from 2 to 876, with mean total flower production and other measures of reproductive output being significantly greater among individuals with multiple stems as compared to single-stemmed plants (Table 1). Single-stemmed plants produced an average of 18.94 seeds per plant, while multi-stemmed plants produced an average of 103.36 seeds per plant. Further study is needed to determine how these reproductive output rates vary among sites and within sites among years.

Table 1. Results of preliminary reproductive output study conducted in a Short's bladderpod population near Hartsville, Tennessee, during 2016 (Krosnick *et al*. in prep).

Variable		Individuals with single flowering stems				Individuals with multiple flowering stems					Kruskal-Wallis Test	
	n	Mean	SD	Median	Range	n	Mean	SD	Median	Range	X^2	P
Total flowers	89	28.0	23.0	21	2–135	82	152.2	156.0	105.5	20–876	97.9	<0.0001
Developed fruit	89	10.7	12.6	6	0–69	82	59.4	66.9	39.5	2–472	80.0	<0.0001
Undeveloped fruit	89	16.4	14.3	12	1–86	82	90.0	119.9	57	0–815	87.8	<0.0001
Total fruit	89	27.1	22.7	20	1–133	82	149.4	155.4	104	20–871	97.5	<0.0001
Seed per fruit (averaged)	27	1.77	0.53	1.67	1–3.33	35	1.74	0.64	1.75	1–4	0.1	0.7527

Irradiance and soil depths were significantly, but weakly, correlated with measures of fecundity (Krosnick *et al*. in prep). Irradiance was most strongly related with fruit production, with proportion of aborted fruits decreasing with increased irradiance. Soil depth was most strongly related, negatively, with increased numbers of flowers and fruit. These relationships were consistent with results of logistic regression models, using multi-stemmed plants as a proxy for

fecundity, which demonstrated a significant (but again weak) relationship between occurrence of multi-stemmed plants and average irradiance, soil depth, and both variables in combination.

2.3.3 Seed Ecology

2.3.3.1 Dispersal

Seed-dispersal of Short's bladderpod has not been studied, though Shea (1993, p. 21) suggested that the seeds might be dispersed by gravity and wind. The small seeds (1.0-1.8 millimeter (mm)) (~0.4 in) of Short's bladderpod (Rollins and Shaw 1973, p. 167) exhibit no morphological adaptations to facilitate widespread dispersal by wind or any other means, thus wind dispersal would only act to disperse the seeds very short distances (~1-2 m (~3.6-7.2 ft)) from the maternal plant. Limited dispersal distance has been demonstrated for other *Physaria* species, such as *P. ludoviciana*, for which Grant *et al*. (2012, p. 68) found highly significant reductions in the abundance of seeds in the seedbank 1-2 m (3.6-7.2 ft) from the mother plant relative to abundance directly adjacent to the mother plant. Cabin *et al*. (2000, p. 296) and Elberling (2000, p. 89) observed similarly short dispersal distances for *P. fendleri* and *P. arctica*, respectively. Although individual seeds are likely only dispersed very short distances by wind, longer distance dispersal could potentially occur if an entire fruiting raceme or branch of a plant were to break off and be transported by wind before seed pods dehisced (Thacker, pers. comm., May 2015). This hypothetical tumble-weed-like means of wind dispersal may occur infrequently, if at all, but could disperse seeds upslope on rising air currents, acting to periodically counter downslope dispersal of seeds by gravity and surface flow. It also is possible that Short's bladderpod is associated with historical travel routes of ungulates, which could have provided an alternative mechanism for dispersal of seeds upslope and over longer distances via soil stuck to hooves (Littlefield, pers. comm, November 20, 2017).

The small seeds of Short's bladderpod will float on a still surface of water for at least one week, but rapidly sink once surface tension is broken by agitation (pers. obs.). Thus, surface flow of water may aid in the short distance dispersal of seeds, but Short's bladderpod exhibits no obvious adaptations for long-distance water dispersal, despite its habitat being associated with close proximity to riverine systems. Production of mucilage by seeds when wetted is common for many species of Brassicaceae (Vaughan and Whitehouse 1971, pp. 386-392, Young and Evans 1973, entire) and in the genus *Physaria* specifically (O'Kane 2010, p. 616). Seed mucilage has ecological implications for dormancy, germination, and several modes of dispersal (Yang *et al*. 2012, pp. 436-437). However, seed mucilage production has not been examined for Short's bladderpod.

Herbivores have been found to limit seed survival in some *Physaria* species, though the influence of herbivory on Short's bladderpod has not been studied. A study of *P. gordonii* (Delph 1986, p. 474) found that 64.6 percent of fruits (3,189 out of 4,940) were consumed prior to dispersal. Grant *et al* (2012, p. 68) found that only 4 percent of *P. ludoviciana* seeds that were dispersed in June remained in the seedbank by November, which they primarily attributed to post-dispersal granivory. Cabin *et al*. (2000, p. 299) found high rates of density-dependent rodent seed predation for *P. fendleri*, but also postulated that some seeds removed could be hoarded by rodents, thus facilitating dispersal.

2.3.3.2   Soil Seed Bank, Germination, and Dormancy

Plot-sampling at Rockcress Hills State Nature Preserve (Kentucky EO number 22) documented years in which no plants were present followed by recruitment of seedlings (KSNPC 2015, p. 2), providing evidence of seedbank formation in natural populations of Short's bladderpod. Persistent seedbanks have been documented for other *Physaria* species (e.g. *Physaria arctica* (Elberling 2000, pp. 88-90), *Physaria fendleri* (Cabin 1996, entire, Hyatt *et al*. 2000, p. 1653)), though published research on the formation, persistence, and demographic contribution of seed banks for *P. globosa* is needed.

Results of unpublished research found that seed densities in soil samples collected from the Indiana population on June 4, 1987, ranged from 750 to 2,533 seeds per m^2 (C. Baskin, pers. comm., January 16, 2014). These samples were placed in an unheated greenhouse and monitored each week through May 7, 1990. Few seeds germinated during the first and second summers, but 20 to 30 percent of seeds germinated the first spring after sowing, and a smaller percentage germinated in the second spring. These results provide an indication that cold stratification is required for breaking physical dormancy in Short's bladderpod, spring is the optimum season for seedling emergence, and populations are capable of forming at least a short-term persistent soil seed bank. However, no seeds germinated after 12 weeks of cold (5°C) stratification in a laboratory experiment (C. Baskin, pers. comm., January 16 2014); this result suggests that colder or fluctuating stratification temperatures and/or other factors are required for breaking seed dormancy and cueing germination.

Although germination studies and/or protocols have not yet been published for Short's bladderpod, results of a germination experiment (Albrecht and Long, unpublished data) initiated on August 21, 2013, indicate that Short's bladderpod seeds have primary physiological dormancy that can be broken with gibberellic acid. Seeds were collected on June 5, 2013, from Tennessee EO number 4, which lies within the River Trace designated critical habitat unit (Unit #8; 79 FR 51030; August 26th, 2014). Seedlings were defined by the emergence of a radicle >1 mm (.04 in). No seeds germinated after 12 weeks under consistently moist conditions in germination incubators set at diurnal temperature regimes (12 h light/12 h darkness) of 15/6°C, 25/15°C, and 35/20°C. However, seeds pre-soaked in 500 parts per million (ppm) of gibberellic acid (GA3) for 24 hours germinated to 60-75 percent across the three temperature regimes over the same time period, whereas seeds pre-soaked in 1:100 solution of liquid smoke germinated to <15 percent. When pre–treated with gibberellic acid, seeds germinated at higher rates under diurnal temperatures typical of late spring/early autumn and summer relative to early spring/late autumn temperatures. This study also demonstrated high viability for the population from which seed was collected for this experiment. Previous studies have also found increased germination in response to gibberellic acid treatments for *Physaria gordonii*, *P. fendleri*, and *P. palmeri* (Bass *et al*. 1966, p. 150, Cruz *et al*. 2013, p. 197).

After-ripening, a mechanism by which seed dormancy is progressively lost during dry storage following harvest of mature seed (Baskin and Baskin 2014, entire), has been observed in several *Physaria* species. Germination of *P. fendleri* and *P. gordonii*, was found to be significantly higher after 12 weeks of storage and warm temperatures relative to shorter storage durations (Cruz *et al*. 2013, p. 196). Seeds of *P. ludoviciana* don't require cold-stratification and exhibit after-ripening, as germination rates for seeds imbied after 6-10 months of storage after harvest were significantly higher than for seeds imbied after only 0-4 months of storage (Grant *et al*.

2012, pp. 69-70). However, other *Physaria* species have shown little difference in germination rates after different storage periods (Cruz *et al*. 2012, pp. 187-188).

Preliminary results from an ongoing seed ecology study, summarized below, provide insights into dormancy-breaking requirements for Short's bladderpod seeds and the potential for populations to form soil seed banks (Dell and Albrecht 2019, pp. 4-8). Stratification treatments, conducted on a 12/12 light/dark cycle, demonstrated greater dormancy loss at 2°C (~36°F) than at 5°C (41°F), and stratification for 90 days at 2°C (~36°F) yielded greater germination than 45 days. Incubation at (68/50°F) was more effective than 15/6°C (59/~43°F), but both produced very low rates of germination after 30 days in treatments lacking cold stratification. The highest mean germination percentages (23%) were achieved with 90 days stratification at 2°C (~36°F), followed by incubation at 20/10°C (68/50°F) for 30 days; though, results were considerably variable within all treatments and populations. After-ripening in laboratory conditions for a period of 9 months had little effect on breaking seed dormancy in Short's bladderpod, indicating that most seeds maintain a strict cold stratification requirement for dormancy loss. Similarly, an ongoing seed burial experiment demonstrated the importance of cold stratification and indicates the potential for populations to form a soil seed bank. Mature seed lots were buried in June at the time of natural seed dispersal, excavated each season over a two-year period, and then incubated in light and darkness at average daily mid-spring/autumn temperatures (20/10°C) (68/50°F). Seeds excavated in the winter and spring germinated to much greater proportions than those excavated in autumn or summer across both years, indicating seeds are capable of dormancy cycling. Across all seasons tested, seeds incubated in light germinated at greater proportions than those in darkness; thus, light appears to be an important germination cue and play a role in the formation of a soil seed-bank. In the second spring, ~60% of seeds were recovered from buried bags, confirming the potential for Short's bladderpod to form a short-term persistent seed bank.

It is not currently known when germination typically occurs in natural populations of Short's bladderpod, though it is possible that seeds germinate in the fall and form rosettes over winter, germinate in the springtime once conditions become favorable, or exhibit either phenology depending upon the dormancy status of individual seeds and variation in seasonal climatic conditions. Laboratory experiments and a seed burial study indicated that most seeds in a cohort germinate in spring, although a small proportion of seeds are capable of germinating in autumn if exposed to light and ample moisture (Dell and Albrecht 2019). During a 2016 study of phenology and pollination in one Tennessee population, initial observation of rosettes occurred on February 8, but it is unknown whether they were from freshly germinated seeds or previously established plants (Thacker *et al*. 2019, p. 32). Previous studies with the genus have shown that seedlings of *P. fendleri* (Cabin *et al*. 1998, p. 1099) and *P. ludoviciana* (Grant *et al*. 2012, p. 73) can germinate in both spring and fall, depending upon the quantity and timing of precipitation. Research is needed to determine whether Short's bladderpod exhibits similar variation in the seasonal timing of seedling emergence and establishment.

2.3.4   Habitat

[Note: For a more detailed description of Short's bladderpod habitat, please see 78 FR 47060 and 78 FR 47109, published on August 2, 2013.]

Short's bladderpod typically grows on steep, rocky, wooded slopes and talus (sloping mass of rock fragments below a bluff or ledge) areas. It also occurs along tops, bases, and ledges of bluffs and infrequently on sites with little topographic relief. The species usually is found in these habitats on south- to west-facing slopes near rivers or streams. Most populations are closely associated with calcareous outcrops (Shea 1993, p. 26). Within the physical settings described above, the most vigorous (Shea 1993, p. 24) and stable (TDEC 2009, p. 1) Short's bladderpod occurrences are found in sites where the forest canopy has remained relatively open over time.

Common woody species associated with Short's bladderpod are *Acer negundo* (box elder), *Acer rubrum* (red maple), *Aesculus glabra* (Ohio buckeye), *Celtis laevigata* (hackberry), *Cercis canadensis* (redbud), *Fraxinus americana* (white ash), *Juniperus virginiana* (eastern red cedar), *Lonicera japonica* (Japanese honey suckle), *Parthenocissus quinquefolia* (Virginia creeper), *Symphoricarpos orbiculatus* (coral berry) and *Ulmus americana* (American elm). Common herbaceous associates include *Alliaria petiolata* (garlic mustard), *Camassia scilloides* (wild hyacinth), *Chaerophyllum procumbens* (spreading chervil), *Delphinium tricorne* (dwarf larkspur), *Galium aparine* (cleavers), *Lamium sp.* (dead nettle), *Phacelia bipinnatifida* (forest phacelia), *Polygonatum biflorum* (Solomon's seal), *Sedum pulchellum* (stonecrop), *Silene virginica* (fire-pink), and *Verbascum thapsus* (common mullein) (Shea 1993, p. 19). On drier sites, Short's bladderpod often is found in vegetation aligned with the *Quercus muhlenbergii – Fraxinus quadrangulata – Juniperus virginiana* (Chinkapin Oak – Blue Ash – Eastern Red Cedar) Woodland Alliance (Pyne 2014).

Although Tennessee and Kentucky populations can include vegetation associated with both xeric and mesic conditions in close proximity, this is especially pronounced in several Kentucky sites, where, for example, mesic species such as *Jeffersonia diphylla* (twinleaf) and *Trillium sessile* (wake-robin) can occur in the shaded understory within a few feet of xeric species such as *Sedum pulchellum* (stonecrop) that grow on exposed rocks (pers. obs.). The canopy at such sites may be less open relative to historical conditions, but the presence of conservative species (i.e. species with a low tolerance of environmental degradation and high fidelity to natural remnant habits, sensu Swink and Wilhem 1994) associated with rich deciduous forest suggests that these sites did historically include some mesic habitats. Although Short's bladderpod appears to be capable of persisting under variable light and moisture conditions, flowering is drastically increased in high-light conditions such as exposed rock outcrops, or powerline cuts through more mesic sites such as Kentucky EO 23 (pers. obs.). This suggests that canopy light gaps, tree-fall, and/or fire may have played an important role in maintaining open conditions conducive to reproduction of Short's bladderpod populations in more forested sites, while edaphic conditions help to inhibit canopy closure of populations on exposed rock outcrops.

2.3.5   *Summary of Individual Ecological Requirements*

The hypothesized life-cycle model in Figure 1 illustrates the life-cycle stages of Short's bladderpod and processes necessary for transitions among those stages to occur. The upper arrow in the model, connecting the adult stage back to the seed stage, indicates potential for seed dormancy and maintenance of a persistent seed bank. The lower arrow, connecting the adult and seedling stages, indicates that at least some seed might germinate and grow into a seedling soon after dispersal and not contribute to maintenance of a persistent seed bank. Table 2 presents a summary of key ecological attributes needed for Short's bladderpod individuals to complete the

species' life cycle. Fitness of Short's bladderpod individuals is dependent on appropriate temperature, soil moisture and nutrients, and light regimes for seed germination, growth of seedlings, rosettes, and adults, and reproduction. Soil moisture is likely to be most limiting during the seedling growth phase, affecting rates of recruitment into the rosette and adult stage classes, but could promote encroachment by woody vegetation if too high. These environmental factors are also influential for growth and flowering in the adult stage class, but availability of mate-compatible genotypes and abundance of pollinators are critical factors for production of viable seed.

Blue circles/white text = Life-cycle stages
Black arrows/black text= demographic vital rates
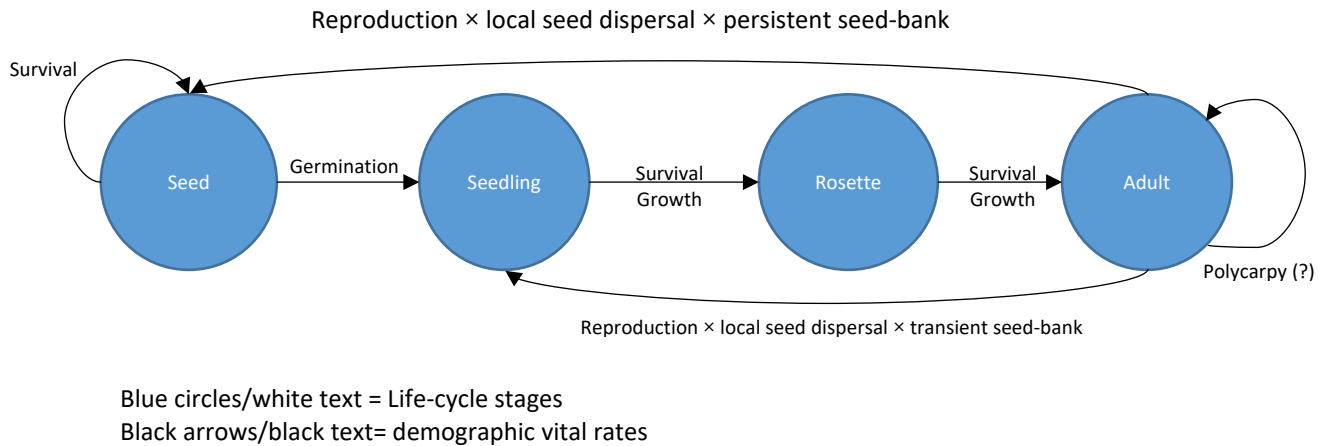
Figure 1. Hypothesized life-cycle model for Short's bladderpod depicting life-cycle stages and processes necessary for transitions among those stages to occur.

Table 2. Key ecological attributes that are hypothesized to influence vital rates and demographic transitions of Short's bladderpod between life-cycle stages depicted in Figure 1.

Life-cycle Stage	Process	Ecological Attributes
Seed	*Dispersal*	Flowing water for dispersal within watersheds
	Germination	Temperature, moisture, light, mechanism to break dormancy
	Seed bank formation	Dormancy, absence of germination cues, undisturbed soils
Seedling and Rosette	*Growth*	Light and soil moisture likely critical for survival and recruitment, nutrients
Adult	*Growth*	Light, soil moisture, nutrients
	Flowering	Light, soil moisture, nutrients
	Seed set	Pollinators, presence of mate-compatible genotypes in the population, absence of predispersal seed predators

2.4 Population-level Ecology

Resiliency is the ability to sustain viable populations in the face of environmental variation and transient perturbations. Population resiliency requires healthy demographic structure and sufficient habitat to provide for a stable or increasing population growth rate (lambda, λ). In terms of demographic structure, populations must consist of a sufficiently large number of unrelated individuals for outcrossing to occur, reducing risks of inbreeding and genetic drift and promoting high rates of viable seed production. Viable populations of pollinators are necessary to facilitate mating via pollen transfer between unrelated individuals. To be resilient, populations should include individuals distributed across all life-cycle stages, including reproductive plants, non-reproductive recruits into the population, and seedlings. Maintenance of a soil seed bank also is a likely requirement for Short's bladderpod populations to be resilient.

2.4.1 *Population Demography and Genetics*

The size of a population influences population resiliency through the processes of demographic and environmental stochasticity. *Demographic stochasticity* is the variation in vital rates (i.e. probabilities of survival and reproduction) among individuals of a given age or life-cycle stage, at a given point in time, while *environmental stochasticity* is variation in vital rates over time, affecting all individuals of a given age or stage similarly (Lande 1988, p. 1457). The number of individuals and demographic structure necessary for populations of Short's bladderpod to be resilient to negative effects of demographic and environmental stochasticity on population growth rates is unknown. Larger populations with stable or increasing growth rates should buffer against stochasticity and improve chances of long-term recovery (Wolf *et al.* 2015, p. 206).

Population size also affects population resiliency through genetic health. The ability of populations to adapt to environmental change is dependent upon genetic variation, a property of populations that derives from its members possessing different forms (i.e., alleles) of the same gene (Primack 1998, p. 283). Small populations occurring in isolation on the landscape can lose genetic variation due to the potentially strong influence of genetic drift, i.e., the random change in allele frequency from generation to generation (Barrett and Kohn 1991, p. 8). Smaller populations experience greater changes in allele frequency due to drift than do larger populations (Allendorf and Luikart 2007, pp. 121-122). Loss of genetic variation due to genetic drift heightens susceptibility of small populations to adverse genetic effects, including inbreeding depression and loss of evolutionary flexibility (Primack 1998, p. 283). Deleterious effects of loss of genetic variation through drift have been termed drift load, expressed as a decline in mean population performance of offspring in small populations (Willi *et al.* 2005, p. 2260).

Despite the potential presence of a mechanism, discussed above, functioning to reduce or eliminate reproductive output among individuals sharing S-haplotypes, in small populations mating is likely to occur among individuals that possess different S-haplotypes but are genetically similar at other loci due to loss of alleles from the population through genetic drift (Byers and Meagher 1992, p. 358). Mating between such closely related individuals is referred to as inbreeding. Inbreeding rates are higher in small populations because most or all individuals in the population are related, and inbred individuals generally have reduced fitness as compared to non-inbred individuals from the same population, a phenomenon referred to as inbreeding depression (Allendorf and Luikart 2007, p. 306).

Evidence in plants of inbreeding depression due to small population size is provided by Heschel and Paige (1995, p. 128), who found that plants from populations of *Ipomopsis aggregata* (scarlet gilia) with 100 or fewer flowering individuals produced smaller seeds with lower rates of germination success compared to those from populations with more than 100 flowering individuals. Heschel and Paige (1995, p. 131) also found that seed sizes increased and germination success improved in response to transfer of pollen into each of the small populations, which they interpreted as evidence that the reduced fitness observed in small populations was attributable, in part, to inbreeding depression.

Willi *et al*. (2005, pp. 2263) found evidence of the three processes described above (reduced cross-compatibility presumably due to lack of compatible mates carrying different S-haplotypes, reduced fitness due to inbreeding, and drift load due to loss of genetic variation) simultaneously affecting small populations of a plant, *Ranunculus reptans* (creeping buttercup). Populations with low allelic diversity, taken as an indication of long-term small population size, had higher inbreeding levels. Inbreeding depression in these populations was expressed as poor clonal performance and reduced seed production in offspring (F1 plants) produced by crosses between plants with high kinship coefficients. Drift load also was expressed as a reduction in mean seed production of F1 plants in long-term small populations (Willi *et al*. 2005, p. 2260).

Research is needed for assessing levels of genetic diversity within populations of Short's bladderpod, genetic differences between populations in the different regions in which the species occurs, and whether gene flow is occurring between populations within each region. A recent study of *Boechera perstellata* (Baskauf *et al*. 2014, pp. 269-273), an endangered species that co-occurs with Short's bladderpod at some Kentucky sites and likewise has a disjunct distribution with populations in Tennessee, revealed substantial genetic divergence among populations in the two states. Given the lack of evident mechanisms for long-distance dispersal for Short's bladderpod, genetic divergence among populations in Kentucky and Tennessee is likely and may influence potential phenotypic variation caused by biological and ecological differences between these regions. Population genetics research could also clarify the origins of the Indiana population.

2.4.2   Habitat

It has been observed that Short's bladderpod populations are most robust in sites where light availability is high due to low levels of shading from midstory and overstory vegetation. Sites where establishment and growth of woody plants are limited by factors including shallow soils, limited water availability, and disturbances that regulate forest development or cause the creation of canopy openings through tree mortality, provide these conditions. Weakly significant relationships between irradiance (positive) and soil depth (negative) with measures of fecundity have been documented (Krosnick *et al*.in prep). Disturbance processes observed to affect vegetation structure at Short's bladderpod sites include drought, ice storms, flooding and landslides. Human-caused disturbance associated with right-of-way maintenance also can affect Short's bladderpod populations through direct effects to individuals or indirect effects from soil disturbance and altered vegetation structure and light availability, with great potential for positive effects if carefully implemented. Invasions by non-native woody plants, including privet (*Ligustrum* spp.) and honeysuckle (*Lonicera* spp.), could decrease light availability during the late winter and early spring, due to earlier leaf emergence than native trees and shrubs, with

potential implications for germination, growth, and reproduction of Short's bladderpod individuals.

Ground-nesting bees are important pollinators for Short's bladderpod (Thacker *et al.* 2019, pp. 32-35), as has been seen in some congeners (Edens-Meier *et al*. 2011, p. 293, Tepedino *et al*. 2012, pp. 143-144). Available data indicate that maintaining cleared or open canopy conditions supports greater numbers of bees, generally, and Halictids in particular (Campbell *et al.* 2007, p. 395-396, Grundel *et al.* 2010, p. 1683, Hanula *et al.* 2015, p. 146). Thus, reducing canopy cover and density of woody vegetation, including non-native shrubs, should enhance growth and flowering in Short's bladderpod and increase abundance of potential pollinators.

Under natural conditions, flooding is likely an infrequent occurrence in most Short's bladderpod sites. But, many Short's bladderpod sites are located along impounded reaches of the Cumberland and Kentucky rivers or their tributaries, where Short's bladderpod can be exposed to prolonged inundation at lower elevation, occupied sites that are vulnerable to reservoir fluctuations. The effect of inundation on Short's bladderpod, either through direct mortality or indirectly through habitat loss from soil erosion due to reservoir fluctuation, is unknown, as is the effect on pollinators from flooding of nests or loss of nesting sites. Landslides have occurred at many sites, especially during the 2010 floods in middle Tennessee, resulting in losses of habitat that could persist indefinitely.

2.4.2.1 Critical Habitat

The Endangered Species Act and its implementing regulations require identification of the physical or biological features essential to the conservation of Short's bladderpod in areas occupied at the time of listing, focusing on the features' primary constituent elements (PCEs). PCEs are those specific elements of the physical or biological features that provide for a species' life-history processes and are essential to the conservation of the species. Based on the Service's understanding of the physical or biological features and habitat characteristics required to sustain the species' life-history processes at the time they were written, the PCEs for Short's bladderpod are:

> (1) Bedrock formations and outcrops of calcareous limestone, sometimes with interbedded shale or siltstone, in close proximity to the mainstem or tributaries of the Kentucky and Cumberland rivers. These outcrop sites or areas of suitable bedrock geology should be located on steeply sloped hillsides or bluffs, typically on south- to west-facing aspects.

> (2) Shallow or rocky, well-drained soils formed from the weathering of underlying calcareous bedrock formations, which are undisturbed or subjected to minimal disturbance, so as to retain habitat for ground-nesting pollinators and potential for maintenance of a soil seed bank.

> (3) Forest communities with low levels of canopy closure or openings in the canopy to provide adequate sunlight for individual and population growth. Invasive, nonnative plants must be absent or present in sufficiently low numbers to not inhibit growth or reproduction of Short's bladderpod.

The Service designates critical habitat based on availability of the PCEs for a given species, delineating those areas determined to be essential for the species' conservation. The Service designated approximately 373 hectares (ha) (925.5 acres (ac)) of critical habitat for Short's bladderpod, distributed among 20 units (Figure 2, Table 3) in Posey County, Indiana; Clark,

Franklin, and Woodford Counties, Kentucky; and Cheatham, Davidson, Dickson, Jackson, Montgomery, Smith, and Trousdale Counties, Tennessee (79 FR 51039; August 26, 2014). There are 20 critical habitat areas that constitute our best assessment of areas that meet the definition of critical habitat for Short's bladderpod, which included all locations that the species was known to occupy at the time it was listed endangered. The approximate area of each critical habitat unit, broken down by land ownership, is shown in Table 3. For a more detailed description of each unit, the features essential to the conservation of the species within each unit, and potential threats to the conservation of the species within each unit, see the Final Designation of Critical Habitat (79 FR 50990-51002; August 26, 2014). For maps of each unit, see 79 FR (51025-51039; August 26, 2014).

While the description of PCEs given above emphasizes the importance of minimizing disturbance to soils for conservation of Short's bladderpod and its pollinators, we acknowledge that maintaining open canopy habitats is also important for this purpose. Anthropogenic disturbances will likely be important in providing suitable vegetation structure and could result in soil disturbance of varying intensity. While Short's bladderpod and its pollinators may tolerate or potentially benefit from low-to-moderate levels of soil disturbance, extensive alteration of soil structure within designated critical habitat should be avoided.
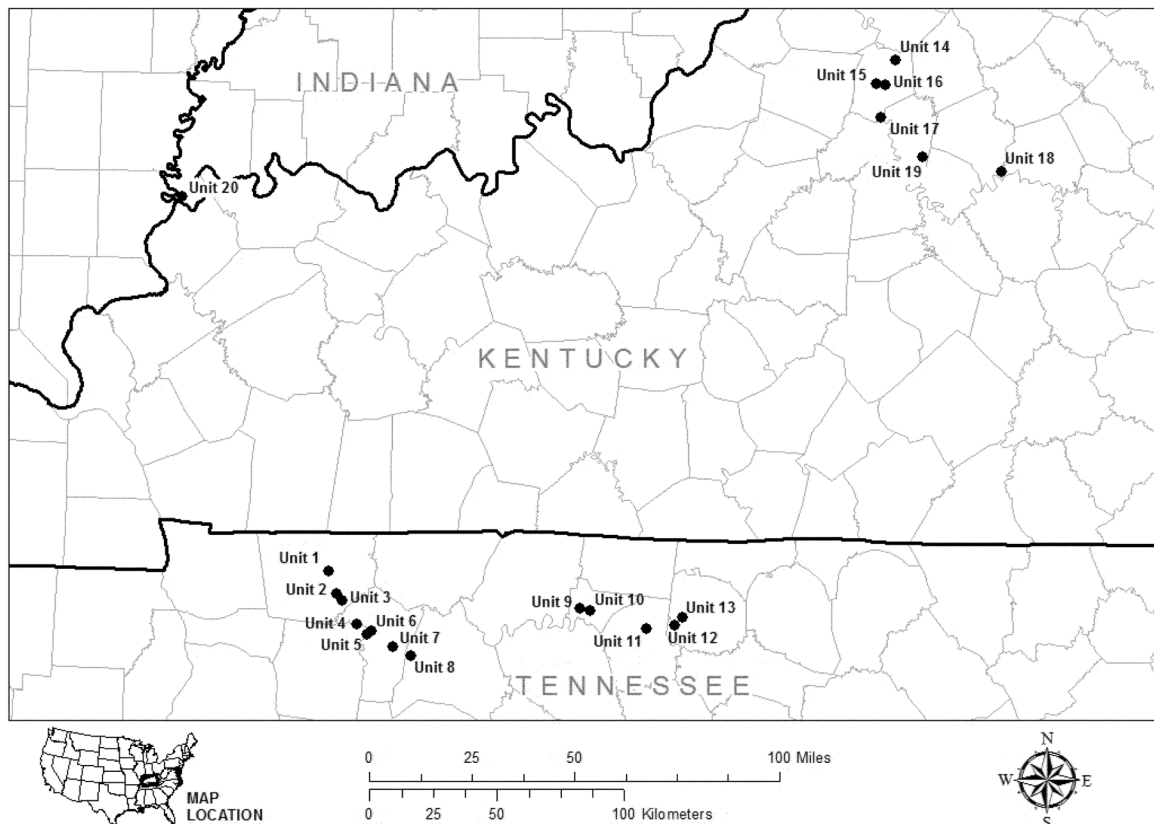

Figure 2. Index map of critical habitat units for Short's bladderpod in Indiana, Kentucky, and Tennessee. For maps of each unit see the Final Designation of Critical Habitat (79 FR 51025-51039; August 26, 2014)

Table 3. Designated critical habitat units for Short's bladderpod in Hectares (ha) and Acres (ac).

Critical habitat unit	Private ha (ac)	State/local ha (ac)	Federal ha (ac)	Size of unit ha (ac)
1. Kings and Queens Bluff	7.6 (18.9)		*3.0 (7.3)	7.6 (18.9)
2. Lock B Road	10.1 (25.0)		*0.3 (0.8)	10.1 (25.0)
3. Jarrel Ridge Road	5.2 (12.8)		*0.4 (1.1)	5.2 (12.8)
4. Cheatham Lake	19.1 (47.2)	3.4 (8.3)	4.9 (12.0)	27.3 (67.5)
5. Harpeth River	8.2 (20.3)		17.3 (42.8)	25.5 (63.1)
6. Montgomery Bell Bridge	2.1 (5.3)		9.0 (22.3)	11.2 (27.7)
7. Nashville and Western Railroad	20.8 (51.4)	8.1 (20.0)	1.5 (3.8)	30.5 (75.3)
8. River Trace	42.8 (105.7)		*5.6 (13.8)	42.8 (105.7)
9. Old Hickory Lake	1.9 (4.8)		2.9 (7.1)	4.8 (11.9)
10. Coleman-Winston Bridge	4.1 (10.1)		3.3 (8.1)	7.4 (18.2)
11. Cordell Hull Reservoir			12.3 (34.2)	12.3 (34.2)
12. Funns Branch			20.8 (51.3)	20.8 (51.3)
13. Wartrace Creek			37.5 (92.6)	37.5 (92.6)
14. Camp Pleasant Branch	17.4 (42.9)			17.4 (42.9)
15. Kentucky River	83.7 (206.7)	9.4 (23.3)		93.1 (230.0)
16. Owenton Road	1.3 (3.3)	1.5 (3.7)		2.8 (7.0)
17. Little Benson Creek	9.4 (23.3)			9.4 (23.3)
18. Boone Creek	5.0 (12.4)			5.0 (12.4)
19. Delaney Ferry Road	0.6 (1.4)			0.6 (1.4)
20. Bonebank Road		1.7 (4.3)		1.7 (4.3)
Total	239.3 (591.5)	24.1 (59.6)	118.8 (297.2)	373.0 (925.5)

Note: Area sizes may not sum due to rounding.
*Indicates U.S. Army Corps of Engineers easements, which are not added to size of unit because these lands are included in ha (ac) figure given for the private lands on which easements are held.

2.4.3   *Summary of Population Ecological Requirements*

In summary, the primary drivers of resiliency of Short's bladderpod populations are healthy genetic and demographic structure and sufficient quality habitat for maintaining positive population growth rate over time (Table 4, Figure 3). The population size and genetic and demographic structure, including sustainable vital (i.e., birth, death, immigration, and emigration) rates, required for maintaining viable populations is unknown, but larger populations composed of individuals from all life-cycle stages should be more resilient to demographic and environmental stochasticity and less vulnerable to loss of genetic variation through the process of genetic drift. Maintaining stable or growing populations requires habitats with low levels of shading from overstory and midstory vegetation, resulting from a combination of disturbances to create canopy openings and shallow soils limiting soil moisture available for uptake by woody plants. Extensive alteration of soil structure should be avoided to maintain sites for ground-nesting pollinators, as should invasion by non-native plants to reduce sources of undesirable shading or competition.

Table 4. Ecological requirements for survival and reproductive success of Short's bladderpod populations.

| Population Health	Attribute	Importance
Healthy Demography	Large Ne	Availability of compatible mates; maintenance of genetic variation
	Sustainable demographic structure and vital rates	Reproduction and recruitment to maintain population growth rate; maintenance of soil seed bank
Suitable Habitat for Maintaining Demography and Population Growth	Shallow or rocky soils with minimal alteration of soil structure	Regulation of canopy and midstory vegetation; pollinator nesting sites; maintenance of soil seed bank
	Adequate light availability	Individual germination, growth, and reproduction; floral resources for pollinator attraction
	Absence or low abundance of invasive woody shrubs	Minimize shading and competition for below-ground resources
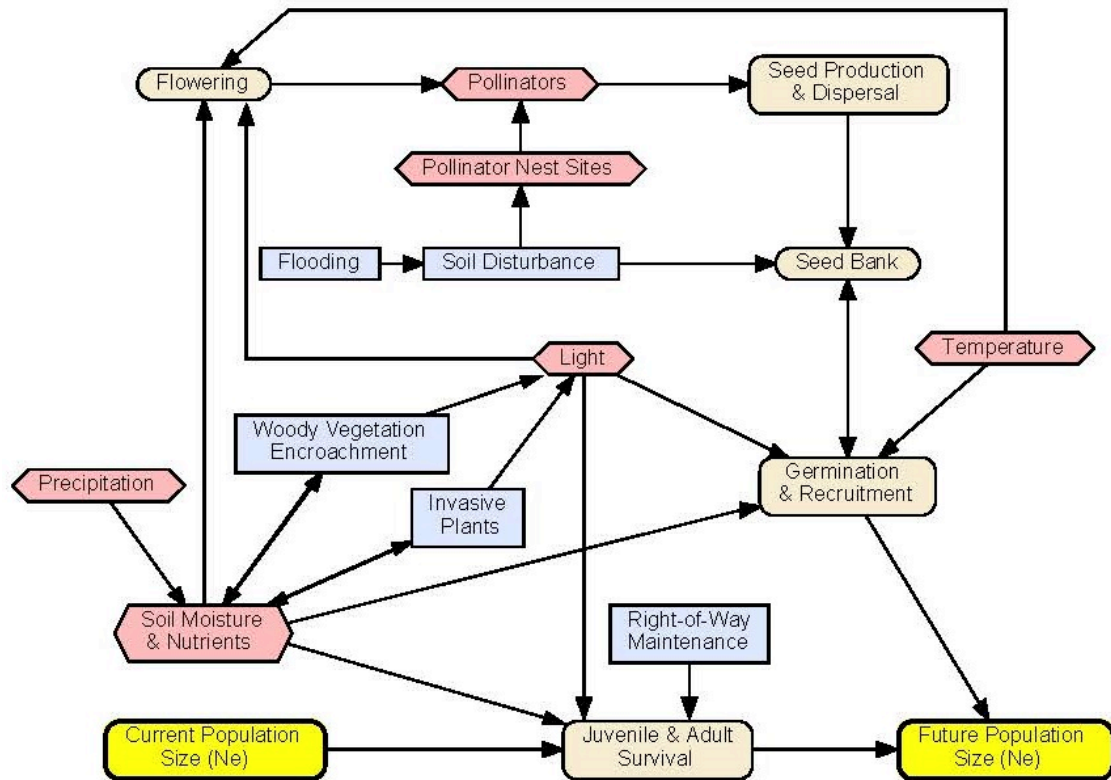
Figure 3. Influence diagram illustrating ecological factors (pink) and demographic processes (tan) needed for sustaining resilient populations (yellow) of Short's bladderpods. Blue boxes represent risk factors negatively affecting Short's bladderpod or its habitat.

2.5 Species-level Ecology

Species-level ecological requirements for Short's bladderpod, in the context of the 3Rs, are discussed below and summarized in Table 5.

2.5.1 Resiliency

Resiliency is the ability to sustain populations in the face of environmental variation and transient perturbations. Short's bladderpod's resiliency as a species is a function of the number and sizes of populations and the distribution of those populations relative to one another, as well as their distribution relative to the degree and spatial extent of environmental stochasticity they face. Generally speaking, the greater number of healthy populations and spatial heterogeneity occupied by the species, the greater likelihood of sustaining populations through time. Healthy populations (i.e., large Ne, positive growth rates, and spatially heterogeneous) are better able to recover from stochastic events and withstand variation in the environment. Thus, the greater number of healthy populations, the more resilient the species is likely to be.

Table 5. Ecological requirements for species-level viability.

3Rs	Requisites of long-term viability	Description
Resiliency	Healthy populations distributed across diversity of environmental and climatic conditions	Populations with large Ne, sustainable demographic structure and vital rates, high light availability, adequate pollinators; dispersed across range of physical and climatic settings
Representation	Maintain adaptive diversity	Healthy populations distributed across range of genetic and phenotypic variation
	Maintain evolutionary processes	Healthy populations and ecological processes intact to provide gene flow, natural selection, genetic drift
Redundancy	Sufficient distribution of healthy populations	Spatial dispersion of populations to guard against catastrophic events eliminating portions of species' adaptive capacity
	Sufficient number of healthy populations	Adequate number of populations to buffer against catastrophic losses of adaptive diversity

2.5.2 Representation

Representation is the range of variation found in a species, and this variation – or adaptive diversity – is the source of a species' ability to adapt to near and long-term changes in the environment. Short's bladderpod's adaptive diversity is a function of the amount and spatial distribution of the genetic and phenotypic diversity the species possesses. By maintaining these two sources of adaptive diversity across a species' range, its responsiveness and adaptability to habitat changes over time is preserved.

2.5.3   Redundancy

Species-level redundancy reflects the ability of a species to withstand catastrophic events, and is best achieved by having multiple, widely distributed populations relative to the spatial occurrence of catastrophic events. Redundancy protects species against the unpredictable and highly consequential events for which adaptation is unlikely, allowing them to withstand catastrophic events.

2.6   Synopsis

Viability is the ability to sustain populations over time. Species with greater numbers (redundancy) of healthy populations (resiliency), encompassing a broad array of ecological and genetic diversity in a spatial arrangement that maintains adequate gene flow (representation), are more likely to be viable. Conserving adaptive diversity in Short's bladderpod requires maintaining a sufficient number of healthy populations across the full breadth of geologic, edaphic, and climatic settings the species has historically occupied in Indiana, Kentucky, and Tennessee. As described in the Population-level Ecology section, healthy populations of this species consist of large numbers of individuals, some portion of which are distantly related or unrelated, distributed across all life-history stages. The most robust populations occupy sites with shallow or rocky soils, where light availability is high due to restricted development of midstory and forest canopy vegetation, and invasive, non-native plant species are absent or present in low numbers.

3   Analysis of Historical and Current Condition

In this section, we describe our framework for assessing the resiliency, representation, and redundancy of Short's bladderpod populations over time. The first step in the assessment is to summarize available information on the species' historical and current distribution, using data provided by Natural Heritage Programs in Indiana (Indiana Natural Heritage Data Center (INHDC) 2019), Kentucky (Kentucky Natural Heritage Program (KNHP) 2020), and Tennessee (Tennessee Natural Heritage Inventory Database (TNHID) 2020). All of these state conservation agencies are members of the NatureServe network, which gathers, manages, and represents data for species and ecological systems using the NatureServe Core Methodology[1]. In addition, we used data from Shea (1993, entire) to better characterize historical conditions for Short's bladderpod.

Natural Heritage Programs (NHP) track locations of species occurrences (i.e., element occurrences, EOs), recording observations over time regarding a species abundance at a given locality. While abundance data generally are in the form of coarse estimates, more precise data are sometimes gathered as part of monitoring programs for rare species.

Short's bladderpod is known from 57 occurrences that have been verified and tracked in NHP databases (Figure 4, Table 6), including one introduced occurrence in Kentucky (EO 30) that was

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[1] http://www.natureserve.org/conservation-tools/standards-methods/natureserve-core-methodology; accessed June 24, 2020

established using seeds from a natural occurrence. If herbarium specimens with insufficient information to verify their locality (Shea 1993, p. 12) are treated as distinct occurrences, rather than imprecise descriptions of known occurrences, then a total of 64 occurrences have been documented for Short's bladderpod (Table 6). For the purposes of analyzing Short's bladderpod's historical and current condition, we treat the 57 occurrences tracked by NHPs as populations.

A rangewide status survey in 1992 (Shea 1993, p. 20) confirmed the presence of Short's bladderpod at 26 sites. These sites are now represented by 25 element occurrences in NHP databases (Table 6) because of differences in mapping of some element occurrences by State conservation agencies compared to Shea's mapping of populations. Two pairs of populations in sites that Shea considered distinct have been combined, based on proximity, into single element occurrences, reducing four populations to two element occurrences. These include Shea
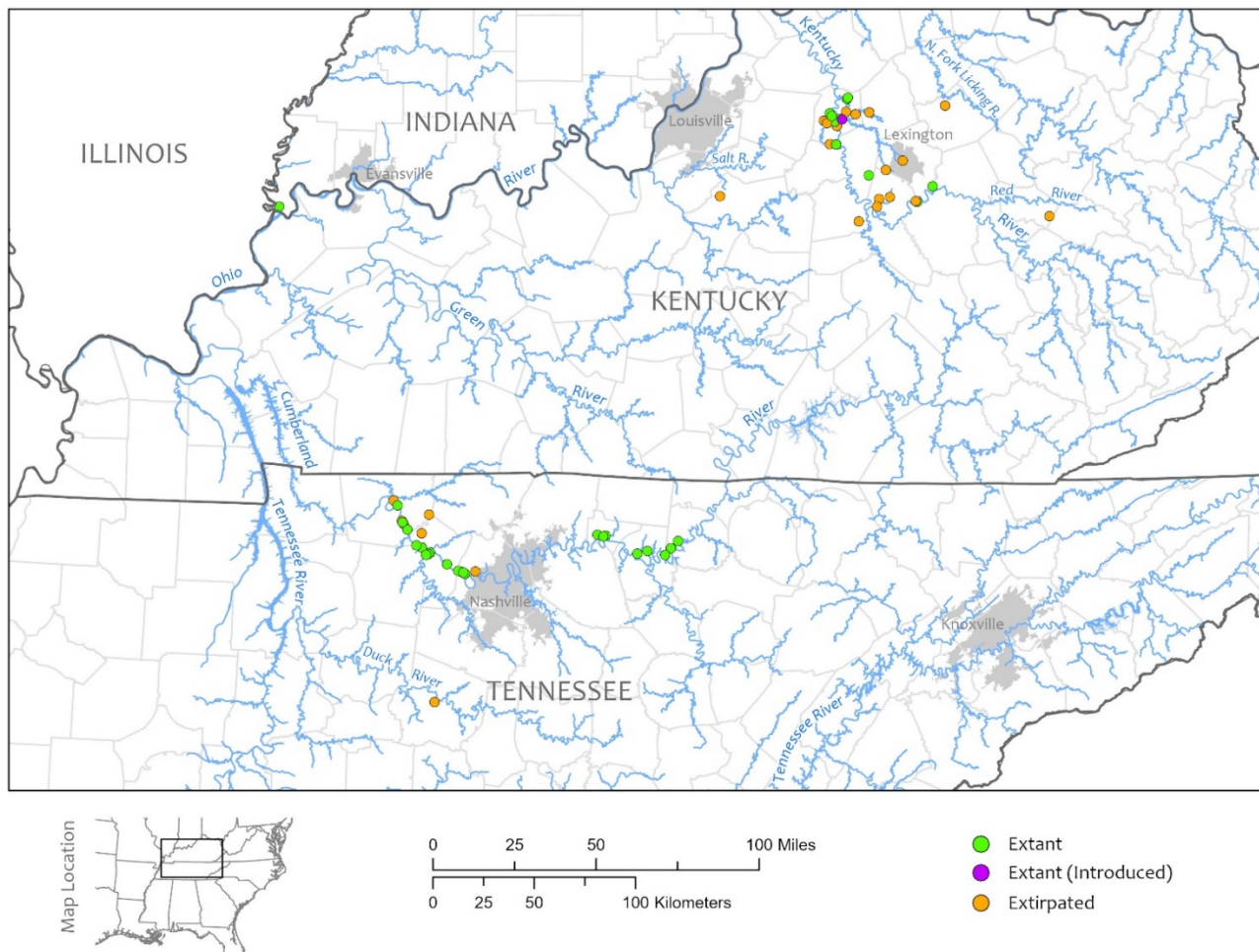

Figure 4. Short's bladderpod distribution map. Green circles represent extant natural populations, with one extant introduced population shown in purple. Orange circles denote occurrences that are extirpated, historical, or could not be located. Data provided by INHDC (2019), KNHP (2020), and TNHID (2020).

Table 6. List of known Physaria globosa occurrences by State and county, with element occurrence (EO) numbers assigned by State natural heritage programs (INHDC (2019), KNHP (2020), TNHID (2020)), numbers assigned to populations reported in Shea (1993), and first and last years of known observations. Abbreviations in status columns are as follows: I = incomplete locality, UC = uncertain, UD = undiscovered, H = historical, E = extant, E* = extant but plants not seen at last observation, X = extirpated

State	County	EO Number	Shea Population Number	Status in Shea (1993)	Status at Listing	2020 Status (NHP data)	EO First Observed	EO Last Observed	Date Plants Last Observed	Estimated Abundance at EO Last Observation	Range of Estimated Abundance
Indiana	Posey	1	1	100s - 1000s	E	E	5/6/1941	6/5/2020	5/19/2017	100s	0 – 1000s
Kentucky	Bourbon	19	2	118	X	X	4/27/1963	4/19/2011	6/9/2005	0	0 - 118
	Clark	1	3	2	E	E*	1957	5/1/2014	5/21/2009	0	0-2
	Fayette	12	38	I	X	X	1931	5/00/1992	5/24/1931	n/a	n/a
		16	37	I	H	H	1892	5/9/1900	5/9/1900	n/a	n/a
	Franklin	2	6	11	X	X	1979-05	5/17/2004	5/4/1992	0	0 - 11
		3	8	4	X	E	1979	4/24/2014	4/24/2014	5 clumps	0 - 5
		4	11, 12	115 (11), 79 (12)	E	E	1979	5/8/2019	5/8/2019	20+	20 - 500
		5	39	I	H	H	1880	6/00/1880	6/00/1880	n/a	n/a
		7	10	48	E	E	1981	4/23/2019	4/23/2019	4	1 - 100
		8	27	UC	X	X	1981	5/24/2011	5/3/1981	0	0 - 37
		11	13	52	E	E	1983	6/1/2003	6/1/2003	Few	few - 52
		14	40	I	H	H	5/00/1856	5/00/1856	5/00/1856	n/a	n/a
		18	4	34	E	E	1992	6/4/2018	6/4/2018	40	20 - 350
		20	5	21	X	X	1992	1999	5/19/1992	0	0 - 89
		21	7	7	X	X	1992	5/13/2004	5/12/1992	0	7
		22	9	42	E	E*	Pre-1990	4/21/2019	5/12/2015	0	0 - 200
		23	14	86	E	E	1990	5/12/2019	5/12/2019	10+	60 - 500
		30[a]	n/a	n/a	n/a	E	4/6/2014	4/23/2019	4/23/2019	62	2 - 62
		n/a	41	I	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Jessamine	6	42	I	H	H	1942	5/16/1942	5/16/1942	n/a	n/a
		13	32	H	X	X	1939	5/00/1992	4/27/1939	n/a	n/a

State	County	EO Number	Shea Population Number	Status in Shea (1993)	Status at Listing	2020 Status (NHP data)	EO First Observed	EO Last Observed	Date Plants Last Observed	Estimated Abundance at EO Last Observation	Range of Estimated Abundance
		17	28	UC	X	X	Pre-1991	5/1/2014	Pre-1991	n/a	n/a
		27	n/a	n/a	X	X	1990	4/20/2011	5/16/1993	0	1 - 7
	Madison	10	43	I	X	E	1903	5/5/2014	5/5/2014	16	0 - 16
	Mercer	24	44	I	X	X	1916	5/12/2011	5/3/1916	0	n/a
	Nelson	25	n/a	n/a	H	H	Pre-1935	Pre-1935	Pre-1935	n/a	n/a
	Powell	15	45	I	H	H	5/6/1923	5/00/1992	5/6/1923	0	n/a
	Scott	9	15	2	X	X	1930	4/19/2011	5/19/1992	0	0 - 2
	Woodford	28	n/a	UD	E	E	5/6/2005	4/28/2019	4/28/2019	11	11 - ~20
Tennessee	Cheatham	1	18	129	E	E	3/2/1956	4/27/2016	4/27/2016	118	100s - 1000s
		14	33	H	X	X	4/29/1969	5/8/2008	4/29/1969	n/a	n/a
		15	17	3	E	E	4/24/1955	4/27/2016	4/27/2016	5 clusters	few – 20
		17	16	19	E	E	4/26/1953	5/15/2019	5/15/2019	1	1 - ~1500
		29	n/a	UD	E	E	5/12/1998	4/27/2016	4/27/2016	129+	~50 – 129
		30	n/a	UD	E	E	5/12/1998	4/27/2016	4/27/2016	16 clusters	10 plants – 16 clusters
		n/a	46 (16?)	I	n/a	n/a	4/24/1955	4/24/1955	4/24/1955	n/a	n/a
	Davidson; Cheatham	10	21, 22	13 (21), 92 (22)	E	E	1935	5/8/2019	5/8/2019	116	10s – 1000s
	Davidson	4	19	~300	E	E	5/16/1971	4/28/2016	4/28/2016	442+	100s – 1000s
		8	34	H	E	E	4/22/1866	4/27/2016	4/27/2016	26 clusters	~50
		9	20	29	X	E	4/16/1974	4/27/2016	4/27/2016	1 cluster	0 – 29
		23	n/a	UD	X	X	5/9/1997	4/23/2008	5/9/1997	0	~200
		n/a	47	I	n/a	n/a	4/27/1940	4/27/1940	n/a	n/a	n/a
	Davidson (Nashville)	n/a	50	I	n/a	n/a	1866	1899	n/a	n/a	n/a
	Dickson	32	n/a	UD	E	E	4/29/2008	4/27/2016	4/27/2016	2	2 plants – 7 clusters

State	County	EO Number	Shea Population Number	Status in Shea (1993)	Status at Listing	2020 Status (NHP data)	EO First Observed	EO Last Observed	Date Plants Last Observed	Estimated Abundance at EO Last Observation	Range of Estimated Abundance
	Jackson	25	n/a	UD	X	E	7/24/1998	4/26/2016	4/26/2016	20+	0 – 20+
		26	n/a	UD	E	E*	5/8/1998	5/14/2019	4/26/2016	0	0 – 17 clusters
		27	n/a	UD	E	E	5/8/1998	5/14/2019	5/14/2019	1	1 plant – 25 clusters
	Maury	7	31	X	X	X	4/23/1955	4/23/1955	4/23/1955	n/a	n/a
		n/a	48	I	n/a	n/a	4/23/1955	4/23/1955	4/23/1955	n/a	n/a
	Montgomery	2	23b	1	X	X	5/7/1968	4/28/1992	4/28/1992	1	n/a
		12	29	UC	E	E	4/27/1946	4/22/2016	4/22/2016	25	10 – 50
		13	30	UC	X	X	5/25/1975	4/30/2013	5/25/1975	0	n/a
		18	35	H	X	X	6/1/1967	4/16/1998	6/1/1967	0	n/a
		22	23a	43	E	E*	4/28/1969	4/30/2013	5/2/2008	0	0 – 50
		28	n/a	UD	E	E	4/23/1998	4/22/2016	4/22/2016	50+	~300
		31	n/a	n/a	X	X	4/9/1979	4/9/1979	4/9/1979	n/a	n/a
		n/a	49	I	n/a	n/a	4/25/1969	4/25/1969	4/25/1969	n/a	n/a
	Smith	20	24	30+	X	E*	5/1/1992	5/14/2019	4/26/2016	0	0 – 200+
		24	n/a	UD	E	E	5/5/1998	5/14/2019	5/14/2019	20+	~10 – 50+
	Trousdale	3	25	40	E	E	5/8/1969	4/17/2019	4/17/2019	50-100	40 – 500
		21	26	~250	E	E	4/30/1992	5/7/2013	5/7/2013	1	100 – 250
		33[b]	n/a	UD	n/a	E	6/4/2014	6/4/2014	6/4/2014	<5	<5
	Williamson	n/a	36	H	n/a	n/a	5/17/1905	4/25/1964	n/a	n/a	n/a

[a] Kentucky EO 30 is an introduced population resulting from seed dispersed by OKNP from EO 18, beginning ca. 2012, but first mapped as an EO in 2014,

[b] Tennessee EO 33 was discovered during 2014 but was not added to the TNHID until 2017.

population numbers 11 and 12, in Kentucky (now EO 4), and 21 and 22, in Tennessee (now EO 10). One Tennessee population that Shea mapped as consisting of two subpopulations (23a, 23b) is tracked in TNHID (2020) as two separate element occurrences (EO numbers 2 and 22). Additional changes that have occurred since the 1992 status survey, leading to the current distribution of Short's bladderpod, include:

- Three historical occurrences that Shea could not verify have been rediscovered – two in Tennessee (EO numbers 8 and 12), in 1998, and one in Kentucky (EO 10), in 2013.
- There have been 13 occurrences discovered by, reported to, or established via introduction by NHPs. This includes Kentucky EO 27, which was apparently discovered in 1990 but not documented by Shea (1993, entire).
- Approximately 20 percent (8 EOs) of all occurrences that were extant during 1992 or later have been extirpated[2]. These include Kentucky EO numbers 2, 9, 19, 20, 21, and 27 and Tennessee EO numbers 2 and 23.

Thus, out of the 57 occurrences of the species tracked in NHP databases, as of 2019 there were 11 extant occurrences in Kentucky, 21 in Tennessee, and 1 in Posey County, Indiana, for a total of 33 extant occurrences rangewide (Table 6) (INHDC 2019, KNHP 2020, TNHID 2020). However, at five of these sites, no Short's bladderpod plants were observed during the most recent monitoring visits, which took place between 2013 and 2019 (Table 6). We consider these occurrences to be extant until such time as they are determined to be otherwise by NHPs in the states where they are located. Extant occurrences in Kentucky are distributed among Clark (1), Franklin (8), Madison (1), and Woodford (1) Counties, and in Tennessee among Cheatham (5), Davidson (3), Dickson (1), Jackson (3), Montgomery (3), Smith (2), and Trousdale (3) Counties. One Tennessee occurrence straddles the county line between Cheatham and Davidson Counties. This is an increase of 7 extant occurrences as compared to the 26 extant occurrences reported in the proposed listing rule for the species (78 FR 47111-47113; August 2, 2013). The rediscovery of Kentucky EO 10 in 2013 also adds Madison County to the species' current range.

There are 24 extant Short's bladderpod occurrences that are located on city, State, or federal lands. The Indiana occurrence is on lands owned by the State of Indiana and managed by the Indiana Department of Natural Resources (IDNR). A portion of one occurrence in Kentucky is located in a State nature preserve owned and managed by OKNP, and one natural and one introduced occurrence are located in the City of Frankfort's Cove Spring Park, where public access is limited. In 2014, an unknown quantity of seeds collected from the natural Cove Spring Park occurrence (EO 18) were sown in a separate location within the park, approximately 1 km (0.6 mi) away, to establish an introduced population (EO 30), where 46 flowering plants and 16 basal rosettes were seen in 2019. In Tennessee, there are 19 occurrences that are entirely or partially located on lands owned or leased by the U.S. Army Corps of Engineers (Corps) adjacent to the Cumberland River. Some of these Corps lands are wildlife management areas (WMA) cooperatively managed by the Tennessee Wildlife Resources Agency (TWRA). The plants at EO numbers 29 and 32 are located in TWRA's Cheatham WMA, and those at EO

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[2] The proposed (78 FR 47111-47112; August 2, 2013) and final (79 FR 44712l; August 1, 2014) listing rules reported that 27 percent of all occurrences had been extirpated, but two Kentucky EOs (3, 10) and three Tennessee EOs (9, 20, 25) have been relocated since the species was listed.

numbers 24 through 27 are located in TWRA's Cordell Hull WMA. Part of one occurrence in Tennessee is located on lands owned by Ashland City.

Using data from NHPs, in combination with other data on ecoregions (Omernick 1987, entire), we characterize Short's bladderpod historical and current conditions with respect to the 3Rs, as described in the following sections.

3.1 Resiliency

For Short's bladderpod to be viable, its populations, or some representative portion of them must be resilient to environmental variation and transient perturbations. Healthy genetic and demographic structure, including presence of a sufficiently large number of unrelated individuals for outcrossing (i.e., large Ne) and sustainable vital rates to occur, and sufficient habitat are necessary for maintaining a stable or increasing population growth rate (lambda, λ). Population genetics and demographic data are not available for Short's bladderpod, so we must rely on estimates of the species' abundance as a surrogate for these attributes in this assessment of the species' resiliency. Habitat sufficiency for Short's bladderpod can be judged by the spatial extent of suitable habitat, degree of canopy openness, and relative abundance of invasive plant species in sites occupied by Short's bladderpod. Maintenance of a soil seed bank and populations of effective pollinators also are necessary for population resiliency, but data are unavailable for assessing these attributes.

The attributes selected for assessing resiliency of Short's bladderpod populations are listed below, with consideration of current data limitations. Monitoring programs for this species should be developed that will provide data for more robust future assessments of resiliency.

- Trend in numbers of occurrences over time.
- Trend in numbers of occurrences with at least 100 individuals. For future assessments, it would be preferable to use stage-specific data, as opposed to estimates of abundance for all life-cycle stages combined, to determine population growth rates and assess whether healthy demographic structure is present. Monitoring programs should collect data on stage-specific abundance, to support assessment of demographic structure.
- Observations of threats related to canopy closure, abundance of invasive plant species, and flooding potential. Shea (1993, pp. 41-92) provided brief statements about threats facing populations included in her status survey of the species. Data on current threats facing populations are limited to anecdotal observations recorded in NHP databases. Monitoring programs should collect data to allow for consistent assessment of stressors affecting populations.

As noted above, Shea (1993, p. 20) confirmed that Short's bladderpod was extant at 26 sites, which are now represented by 25 element occurrences in NHP databases (Table 6), and observed less than 100 plants at 18 of these locations, where estimated abundance ranged from 1 to 86 plants. There were seven occurrences where abundance ranged from a low of 105 to a high estimate, at the Indiana site, of thousands of individuals. With the exception of three of the 25 sites, Shea (1993, pp. 41-92) observed one or more of the following threats at each extant location: roadside maintenance, trash dumping, overstory shading, poor plant health, invasive species, grazing, and small population size.

Short's bladderpod is currently extant at 33 occurrences across its range (Table 6). As noted above no plants were observed at five of these sites during the most recent visits, but we consider them extant until NHP data indicate that otherwise is true. The most recent estimates of abundance, obtained during site visits between 2013 and 2019, indicate that fewer than 100 individuals were present at last observation of 28 sites. There were only 5 sites where estimated abundance exceeded 100 individuals during the most recent observations, ranging from 116 to a few hundred plants. Data from NHPs include observations of threats at all but 4 of the 33 extant sites; though, recent data on threats have not been consistently recorded among sites, as they were by Shea (1993, pp. 41-92). While only recorded at 29 sites, it is likely true that all extant sites face one or more of the following threats: roadside maintenance, overstory shading, invasive species, flooding, and small population size.

At some sites, the most recent surveys did not cover the full extent of suitable habitat or were conducted after flowering, potentially reducing detectability of Short's bladderpod (TNHID 2020). Difficulty in accessing some Tennessee sites, due to their location on steep slopes adjacent to reservoirs, has limited data collection to estimating numbers of clusters of plants, rather than estimating individuals. Lacking information on numbers of plants per cluster, we have conservatively treated each cluster as a single plant for assessing resilience. Despite the potential that abundance was underestimated at some sites, we used the results from these surveys, conducted by state conservation agencies, for assessing resilience because they were the best available data. Therefore, it is possible that true abundance is underscored for the resilience assessment. This fact underscores the need for monitoring to be conducted with standardized methods at optimal times and throughout the full extent of potentially suitable habitat at each occurrence.

Based on these data, it is evident that the historical and current distributions of Short's bladderpod are characterized primarily by populations of low resiliency, owing to small population sizes and presence of threats to either the species, its habitat, or both. The vulnerability of small populations is borne out by the turnover in occurrences between the time that Shea (1993, entire) completed a status survey for the species and present day, resulting in the loss of at least 8 occurrences since 1992. With regard to the species' overall resilience, the discovery of additional, albeit small, populations in Tennessee since 1992 have potentially offset these losses.

3.2 Representation

For conservation efforts to effectively contribute to viability of Short's bladderpod, they must result in an adequate distribution of resilient populations that encompass the full range of the species' adaptive diversity. As discussed above, adaptive diversity is a function of the phenotypic and genetic diversity exhibited by a species. Lacking data on the range of these two attributes of Short's bladderpod populations, we must use the species' distribution across a range of environmental conditions as a proxy that we assume represents its range of phenotypic and genetic variation.

Extant occurrences in Tennessee are located primarily on xeric, south- to southwest-facing, steep hills or bluffs adjacent to the Cumberland River, within the Western Highland Rim and Outer Nashville Basin EPA Level IV Ecoregions (ecoregions) (Omernick 1987, entire). Three occurrences in Cheatham County are adjacent to the Harpeth River near its confluence with the

Cumberland River. One extirpated occurrence was located in the Western Pennyroyal Karst Plain ecoregion, where the species is no longer represented.

Extant occurrences in Kentucky are located primarily on bluffs and steep hillsides adjacent to the Kentucky River or its tributaries within the Hills of the Bluegrass and Inner Bluegrass ecoregions. Two occurrences, one historical and one extirpated, were located in the Outer Bluegrass ecoregion, and another historical occurrence was located in the Northern Forested Plateau Escarpment ecoregion. In contrast to the typically xeric Tennessee sites, some Kentucky sites are characterized by mesophytic sheltered slopes, with some occurrences extending upslope into drier, open juniper-dominated cliff tops (Braun 1950 cited in Shea 1993, pp. 18-19). Adding to the range of habitat variation, plants at Kentucky EO 28 were first found occupying flat areas associated with a spring head; and two historical sites (Kentucky EO 13, Tennessee EO 7) were apparently located on sites with flat to rolling topography, suggesting that Short's bladderpod might not currently occupy the full range of habitats where it was once represented (Littlefield, pers. comm., November 20, 2017, Shea 1993, p. 115).

The occurrence in Indiana, rediscovered in 1985 after not having been observed since its discovery in 1941 (Homoya and Abrell 1986, p. 431), is within the Wabash-Ohio Bottomlands ecoregion on a site underlain by undifferentiated outwash from the Wisconsinan glaciation (Indiana Geologic Survey 2002), as opposed to the calcareous geology on which the species occurs in Kentucky and Tennessee. The ecological relevance of the natural substrate at this occurrence should be cautiously interpreted, given that the population's existence could be an artifact of the soil conditions in the gravelly margins of the adjacent roadbed and the relatively open canopy conditions generated by road and powerline right-of-way maintenance, in contrast to surrounding forested habitat. Although the population may not have existed prior to anthropogenic alteration of habitat via road and powerline construction, the population has persisted and has numbered in the hundreds to more than a thousand individuals in the past. In addition, the population may contain unique genotypes and is relevant for conservation of the species.

We assume that conservation of resilient Short's bladderpod populations within each of the ecoregions discussed above should capture existing adaptive diversity within the species. As noted above, field observations indicate that populations in Kentucky exhibit a biennial life history, while at least some in Tennessee exhibit a polycarpic, perennial life history. This species may act as a facultative biennial or perennial in response to local climatic and habitat conditions. Alternatively, given the certain lack of gene flow between the Cumberland River populations and those near the Kentucky River, there may be a genetic basis for potential differences in longevity among these regions. A study of *Boechera perstellata* (Braun's rockcress), an endangered species with disjunct populations in Tennessee and Kentucky, similar to Short's bladderpod, revealed substantial genetic divergence among populations in the two states (Baskauf *et al*. 2014, pp. 269-273).

In addition to representing presumed phenotypic and genetic variation, maintaining populations across the range of ecoregions the species currently occupies is relevant for representing environmental variation to which the species is adapted and decreasing the risk that stochastic events could threaten all populations with equal severity simultaneously. The extant populations in Kentucky and Indiana lie within a range of latitude encompassing 37.75°N to 38.33°N. Populations in Tennessee lie within a range of latitude encompassing 36.19°N to 36.53°N.

These two portions of the species' range differ with respect to drought frequency and duration, as described below.

To evaluate drought frequency and duration in these two regions, we used data from the U.S. Drought Monitor (http://droughtmonitor.unl.edu/, accessed on February 6, 2017) for the period January 4, 2000, through January 31, 2017. Specifically, we identified all periods of two or more weeks in length during which each county currently occupied by Short's bladderpod experienced drought conditions classified as "D2-Severe" or worse. A D2-Severe Drought is described as one in which crop or pasture loss is likely, water shortages are common, and water restrictions might be imposed. The results of our analyses indicate that the counties occupied by Short's bladderpod in Tennessee experienced a greater cumulative number of weeks of drought during the period examined (Figure 5) and, in several instances, experienced droughts of considerably longer duration (Figure 6), as compared to the counties where the species occurs in Indiana and Kentucky.
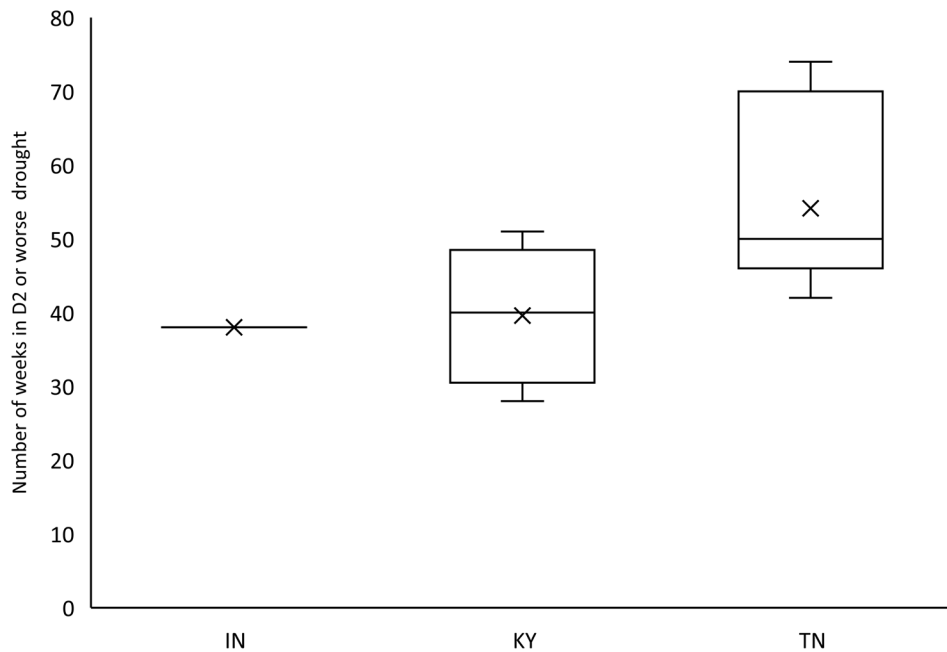

Figure 5. Box plot of cumulative number of weeks of D2-Severe or worse drought experienced in counties occupied by Short's bladderpod in Indiana, Kentucky, and Tennessee during the period January 4, 2000, through January 31, 2017.
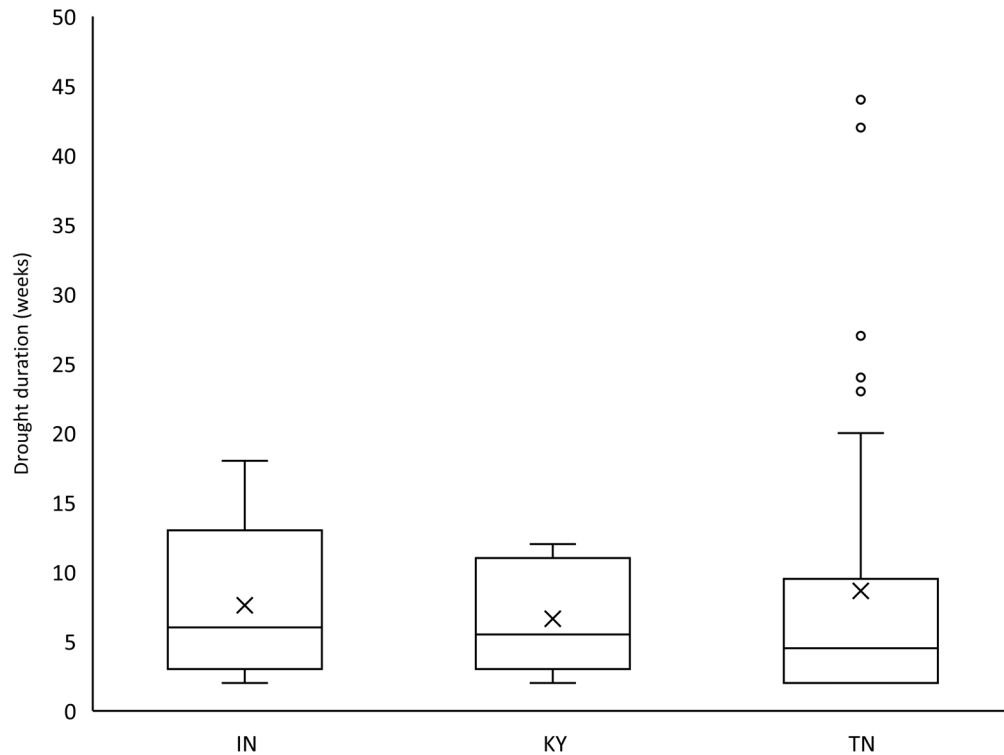
Figure 6. Box plot of duration of individual D2-Severe or worse drought events experienced in counties occupied by Short's bladderpod in Indiana, Kentucky, and Tennessee during the period January 4, 2000, through January 31, 2017.

For the reasons discussed above, we have selected the following as measures of representation for populations of Short's bladderpod: trend in number of ecoregions, states, and counties occupied. The species representation has changed between 1992 and 2019 with respect to the ecoregions and counties where it occurs (Table 7). The species is still extant in Kentucky, Indiana, and Tennessee. The species' representation has increased in terms of numbers of counties occupied, from 10 in 1992, to 12 in 2019; despite extirpation from two counties during that time span. The Bourbon County occurrence, where 118 Short's bladderpod were present in 1992, and a smaller occurrence in Scott County are considered extirpated but occurrences have been discovered in Madison and Woodford counties. Shea (1993, p. 13) conducted limited searches in Madison County, based on incomplete locality information from an herbarium specimen, but did not find the species. Data from the KNHP (2020) indicate that this historical occurrence in Madison County was rediscovered during 2013 and the occurrence in Woodford County was first found in 2005. In Tennessee, the species was discovered in Dickson and Jackson counties after 1992 and is still present in all counties where Shea (1993, entire) documented extant populations. The loss of the population in Bourbon County, Kentucky, represents the loss of the only population known from the Outer Bluegrass ecoregion; though, the species still occupies sites in the Inner Bluegrass and Hills of the Bluegrass ecoregions in Kentucky. There has been no change since 1992 in the number of ecoregions occupied within Tennessee.

Table 7. Historical (ca. 1992, data from Shea (1993)) and current total number of occurrences and number of occurrences with ≥ 100 individuals, in each state, ecoregion, and county.

State	EPA Level IV Ecoregion	County	Shea (1993)		2020 Status	
			Number of Occurrences	Number of Occurrences with ≥ 100 individuals	Number of Occurrences	Number of Occurrences with ≥ 100 individuals
Indiana	Wabash-Ohio Bottomlands	Posey	**1**	**1**	**1**	**1**
Kentucky	Outer Bluegrass	Bourbon	**1**	**1**	**0**	**0**
	Inner Bluegrass	Clark	1	0	1	0
		Franklin	2	1	1	0
		Scott	1	0	0	0
		Woodford	0	0	1	0
		Total	**4**	**1**	**3**	**0**
	Hills of the Bluegrass	Franklin	8	0	7	0
		Madison	0	0	1	0
		Total	**8**	**0**	**8**	**0**
Tennessee	Western Highland Rim	Cheatham	3	1	5	2
		Davidson/Cheatham	1	1	1	1
		Dickson	0	0	1	0
		Montgomery	2	0	3	0
		Total	**6**	**2**	**10**	**3**
	Outer Nashville Basin	Davidson	2	1	3	1
		Jackson	0	0	3	0
		Smith	1	0	2	0
		Trousdale	2	1	3	0
		Total	**5**	**2**	**11**	**1**
		Overall Total	**25**	**7**	**33**	**5**

3.3 Redundancy

Maximizing Short's bladderpod's viability as a species requires not only that populations are distributed across the full range of the species' adaptive diversity, but that there also is adequate redundancy of resilient populations within each representational unit. Conserving multiple resilient populations within each unit decreases the risk that a significant proportion of the species' adaptive diversity could be lost to stressors affecting the species with great intensity at a particular point in space and time. We have chosen to evaluate redundancy of Short's bladderpod by examining trends in total number of extant occurrences and number of occurrences with ≥100 individuals per ecoregion, state, and county (Table 7). While the total number of occurrences has increased from 25, in 1992, to 33 as of 2019, redundancy of populations with ≥100 individuals per ecoregion, state, and county have all declined as discussed below.

The one Indiana occurrence, located in the Wabash-Ohio Bottomlands ecoregion, has apparently decreased in number from an estimated hundreds-to-thousands of plants in 1992 (Shea 1993, p. 42) to a few hundred plants in 2020 (Keller pers. comm.). No plants were observed during site visits in 2018 and 2019, due to prolonged inundation of the site during both years. However, the

observation of a few hundred plants in 2020 marks the first time that more than 100 plants have been observed at this site since 2012. While redundancy is lacking in this representative unit, resiliency of the single population has apparently improved since the species was listed as endangered in 2014.

As of 1992, there were 13 Short's bladderpod occurrences in Kentucky, with 10 of those occurrences in Franklin County and one occurrence each in Bourbon, Clark, and Scott counties. These occurrences were distributed among the Hills of the Bluegrass (8), Inner Bluegrass (4), and Outer Bluegrass (1) ecoregions. Only two occurrences consisting of at least 100 individuals were known from Kentucky, one each in Bourbon and Franklin counties, located in the Outer Bluegrass and Inner Bluegrass ecoregions, respectively. The most recent data available indicate that there are now 11 extant occurrences in Kentucky, with the greatest concentration still in Franklin County, albeit reduced from 10 to 8 occurrences. One of the Franklin County occurrences was introduced by sowing seeds collected from the nearest occurrence. Redundancy is greatest in the Hills of the Bluegrass ecoregion, with eight occurrences, and the remaining three occurrences are in the Inner Bluegrass ecoregion. Available data indicate that there are no occurrences in Kentucky where at least 100 individuals were present during the most recent surveys.

Eleven extant occurrences were known from Tennessee in 1992, six in the Western Highland Rim ecoregion and five in the Outer Nashville Basin as of 1992. The only Tennessee County with more than three occurrences in 1992 was Cheatham. Three occurrences were in Davidson County (one straddling the Cheatham-Davidson county line), two each in Montgomery and Trousdale counties, and one in Smith County. Two occurrences each in the Western Highland Rim and Outer Nashville Basin ecoregions consisted of at least 100 individuals. Today there are 10 occurrences located in the Western Highland Rim and 11 in the Outer Nashville Basin. Cheatham County still has the greatest number of occurrences, up to five from the three that were known in 1992. Available data indicate that there are 3 occurrences in the Western Highland Rim and 1 in the Outer Nashville Basin with at least 100 individuals.

4   Risk and Conservation Factors

In this chapter, we review the negative and beneficial factors affecting Short's bladderpod and describe future scenarios applied to forecast the future condition of the species. Factors that have a negative impact on Short's bladderpod individuals are referred to as risk factors (also as stressors or threats) (Figure 3); factors that have a beneficial effect are referred to here as conservation factors. We begin with describing the most prominent risk factors, based on the best available data, and conservation actions that have occurred in some locations. Next, we describe the analyses undertaken to develop future factor scenarios for forecasting the distribution and abundance of Short's bladderpod into the future.

4.1   Risk Factors

Below, we present a summary of risk factors affecting Short's bladderpod and its habitats. A detailed evaluation of factors affecting the species can be found in the proposed listing (78 FR 47109; August 2, 2013). The loss and degradation of habitat represents the greatest threat to

Short's bladderpod, and is further confounded by small population sizes. The main causes for habitat loss and degradation are construction and ongoing maintenance of transportation rights-of-way; prolonged inundation and soil erosion due to extreme precipitation, flooding, and water level manipulation; canopy shading due to forest succession; and competition from invasive plant species. In 2019, the risk of habitat loss to natural landslides was first documented as a threat to some populations in Tennessee (TNHID 2020). Residential development and impacts from recreational activity (i.e., rock climbing) have been documented as threats in separate, isolated cases, each affecting only a single occurrence. While future effects of climate change cannot be predicted with certainty, we discuss risk factors that could result from general forecasts of change for the regions where Short's bladderpod occurs.

4.1.1 *Transportation and Utility Right-of-Way Construction and Maintenance*

Road construction has caused loss of habitat and population extirpation at five Short's bladderpod occurrences, and roadside maintenance or road widening could adversely affect over 40 percent of the remaining occurrences. In addition to the outright destruction of suitable habitat by road-widening and other construction activities, poorly timed mowing or indiscriminate herbicide application could damage populations that occur in part or entirely within roadside habitats. While 14 of the known extant occurrences are located along roadsides, where maintenance activities such as mowing or herbicide application could affect them, there have been few documented examples of such effects. In many roadside locations, Short's bladderpod occurs on steep slopes or bluffs, where roadside maintenance would be unlikely to affect the species unless the road were to be widened, requiring alteration or removal of the slope or bluff. Moreover, well-timed and carefully executed right-of-way maintenance intended to control vegetation encroachment could be beneficial by reducing shading and competition. Importantly, such maintenance should be timed to avoid disrupting growth and reproduction of Short's bladderpod during the springtime and early summer. Despite the potential habitat improvements associated with careful roadside maintenance, the potential exists for road widening projects or vegetation management efforts along road rights-of-way to destroy or modify habitat, cause mortality of individual plants, or diminish reproductive output at a large proportion of sites where the species occurs. In some instances, utility infrastructure is located in these rights-of-way, increasing potential for adverse effects of right-of-way construction and maintenance.

There are eight extant Short's bladderpod occurrences, and two sites from which the species is thought to be extirpated, located in or adjacent to the Old Tennessee Central Railroad right-of-way (TDEC 2009, p. 3, TNHID 2020), portions of which are not actively used and maintained or have been sold to other rail companies. The Nashville Area Metropolitan Planning Organization (NAMPO 2010, p. 98) 2035 Regional Transportation Plan reported that the Old Tennessee Central Railroad, which follows the Cumberland River and passes through Ashland City, was found to be the most practical alignment for a proposed commuter rail to improve intercity commute options between the cities of Nashville and Clarksville, Tennessee. An updated Regional Transportation Plan extending through 2040 recommends this transit option be developed "over the long-term" (Greater Nashville Regional Council 2016, p. 6-9). Similarly, the Northwest Corridor Transit Study includes development of this commuter rail in its longer term (i.e., 15 years or more) vision (Regional Transportation Authority of Middle Tennessee 2017, p. ES-2). Habitat modification or destruction resulting from such development could

potentially affect 24 percent of the known extant occurrences of the species, including some occurrences where the species is most abundant. Conversely, vegetation encroachment, leading to increased shading and competition, along abandoned railway sections also poses a threat to Short's bladderpod.

4.1.2   Flooding and Water Level Fluctuation

Impoundments and artificial water level manipulation have been noted as stressors to several Short's bladderpod occurrences (Shea 1993, pp. 22-23, TDEC 2009, p. 2). Flooding and water level fluctuation on unregulated reaches of rivers can also threaten occurrences. Notably, the occurrence in Posey County, Indiana is periodically inundated by floodwaters from the Wabash River. Prolonged flood events have been documented to cause mortality of most Short's bladderpod plants and eliminate the recruitment of seedlings into this population during such events (Homoya, pers. comm., November 2012). In Tennessee, all or part of four extant occurrences are vulnerable to the effects of ordinary water level fluctuation in reservoirs operated by the Corps of Engineers, as evidenced by observed erosion within the fluctuation zone, where plants are sometimes located (TNHID 2020). Furthermore, these occurrences in Tennessee are small and vulnerable to extirpation from even limited habitat alteration or inundation. Four additional sites in Tennessee would be vulnerable to extreme fluctuations that could result during low frequency, extreme flood conditions.

4.1.3   Overstory Shading

The most vigorous (Shea 1993, p. 24) and stable (TDEC 2009, p. 1) Short's bladderpod occurrences are found in locations where the canopy has remained relatively open over time. Overstory shading has been implicated as a factor contributing to the extirpation of four occurrences (Shea 1993, p. 4), and has been identified as a limiting factor at 30 percent of remaining extant occurrences throughout the range of the species (INDHC 2019, KNHP 2020, TNHID 2020).

4.1.4   Competition with Nonnative Plant Species

Competition, including the effects of shading from invasive, nonnative herbaceous and shrub species, is cited as a threat to some occurrences throughout the range of Short's bladderpod in Kentucky, Tennessee, and Indiana (KNHP 2020; TNHID 2020; Homoya, pers. comm., December 2012). The species most often mentioned by these agencies include *Lonicera japonica* (Japanese honeysuckle), *L. maackii* (bush honeysuckle), *Alliaria petiolata* (garlic mustard), and *Bromus tectorum* (downy brome grass); however, several other invasive, nonnative species occur in sites where Short's bladderpod exists, including *Ligustrum* spp. (privet), *Rosa multiflora* (multiflora rose), and *Glechoma hederacea* (ground ivy). Competition with or shading from these species adversely affects Short's bladderpod. This stressor has been specifically noted in NHP databases for over half of known extant occurrences, but the impact of invasive species is likely more widespread than what has been reported in occurrence database records.

4.1.5   Natural Landslides

The loss or reduction of habitat for Short's bladderpod due to natural landslides was first documented as a threat, at six extant occurrences, during monitoring of populations in Tennessee

in 2019 (TNHID 2020). Available data are currently insufficient for evaluating whether natural landslides have contributed to extirpations of occurrences or the extent to which they have caused reductions in available habitat at extant occurrences. Continued monitoring of this threat, including estimates of area affected, is needed in order to understand its causes and severity.

4.1.6   Climate Change

While climate has changed in recent decades in regions where Short's bladderpod occurs, and the rate of change likely will continue to increase into the future, we do not have data to accurately determine how the habitats Short's bladderpod, or the habitats it occupies, will respond to these changes. Estimates of the effects of climate change using available climate models lack the geographic precision needed to predict the magnitude of effects at a scale small enough to discretely apply to the range of Short's bladderpod. However, data on trends and predicted changes for the Southeast and Midwest United States (Karl *et al.* 2009, pp. 111-122) provide some insight for evaluating the potential threat of climate change to the species. Most of the range of Short's bladderpod lies within the geographic area included by Karl *et al.* (2009, pp. 111-122) in their summary of regional climate impacts affecting the Southeast region; however, the Indiana occurrence of the species lies in the Midwest region, just west of its boundary with the Southeast region.

Since 1970, the average annual temperature across the Southeast has increased by about 2 °F, with the greatest increases occurring during winter months. The geographic extent of areas in the Southeast region affected by moderate to severe spring and summer drought has increased over the past three decades by 12 and 14 percent, respectively (Karl *et al.* 2009, p. 111). These trends are expected to increase. Rates of warming are predicted to more than double in comparison to what the Southeast has experienced since 1975, with the greatest increases projected for summer months. Depending on the emissions scenario used for modeling change, average temperatures are expected to increase by 4.5 °F to 9 °F by the 2080s (Karl *et al.* 2009, p. 111). While there is considerable variability in rainfall predictions throughout the region, increases in evaporation of moisture from soils and loss of water by plants in response to warmer temperatures are expected to contribute to increased frequency, intensity, and duration of drought events (Karl *et al.* 2009, p. 112).

Projected increases in winter and spring rainfall for the Midwest region, as well as predictions of more intense rainfall events throughout the year, are expected to lead to more frequent flooding, which could intensify the threats to the Indiana population discussed above. Despite these projected trends, the likelihood of drought is expected to increase in the Midwest due to warming-induced increases in evapotranspiration rates and longer intervals between precipitation events (Karl *et al.* 2009, pp. 120-121).

Depending on timing and intensity of drought events, Short's bladderpod could be adversely affected by increased mortality rates, reduced reproductive output due to loss or reduced vigor of mature plants, and reduced rates of seed germination and seedling recruitment. Increases in soil temperatures and soil moisture evaporation in response to predicted ambient warming could accelerate rates of soil seed bank depletion by increasing the seedling mortality rate (Ooi 2012, pp. S54–S55) and diminish the resilience of Short's bladderpod populations by reducing the species' ability to maintain soil seed banks.

4.1.7 Stressors Resulting from Small, Geographically Isolated Populations

Many populations of Short's bladderpod are small and geographically isolated from other populations, and thus have a greater susceptibility to stochastic loss of genetic diversity, inbreeding depression, and related declines in fitness (Primack 1998, p. 283, Willi *et al*. 2005, p. 2260, Allendorf and Luikart 2007, pp. 121-122, p. 306). Evidence in plants of inbreeding depression due to small population size is provided by Heschel and Paige (1995, p. 128), who found that plants from populations of *Ipomopsis aggregata* (scarlet gilia) with 100 or fewer flowering individuals produced smaller seeds with lower rates of germination success compared to those from populations with more than 100 flowering individuals. Heschel and Paige (1995, p. 131) also found that seed sizes increased and germination success improved in response to transfer of pollen into each of the small populations, which they interpreted as evidence that the reduced fitness observed in small populations was attributable, in part, to inbreeding depression.

Willi *et al*. (2005, pp. 2263) found evidence of the three processes described above (reduced cross-compatibility presumably due to lack of compatible mates carrying different S-haplotypes, reduced fitness due to inbreeding, and drift load due to loss of genetic variation) simultaneously affecting small populations of a plant, *Ranunculus reptans* (creeping buttercup). Populations with low allelic diversity, taken as an indication of long-term small population size, had higher inbreeding levels. Inbreeding depression in these populations was expressed as poor clonal performance and reduced seed production in offspring (F1 plants) produced by crosses between plants with high kinship coefficients. Drift load also was expressed as a reduction in mean seed production of F1 plants in long-term small populations (Willi *et al*. 2005, p. 2260).

Fewer than 100 plants have ever been observed at one time at 18 (55 percent) of the 33 extant occurrences, and many of these occurrences are distantly isolated from other occurrences. The likelihood that Short's bladderpod is self-incompatible compounds the threat related to small population sizes. Genetic incompatibility prevents self-fertilization or reduces successful breeding among closely related individuals, which can decrease mean fitness in small populations due to diminished chances for pollination by a compatible mate (Willi *et al*. 2005, p. 2263). Furthermore, these adverse genetic effects of small population size reduce the resilience of Short's bladderpod to recover from other stressors affecting the species and its habitat.

4.1.8 Cumulative Effects

Where two or more threats affect Short's bladderpod occurrences, the effects of those threats could interact or be compounded, producing a cumulative adverse effect that rises above the incremental effect of either threat alone. The most obvious cases in which cumulative adverse effects would be significant are those in which small populations are affected by threats that result in destruction or modification of habitat. Of the 28 populations where less than 100 individuals were present during the most recent count, observations recorded by NHPs indicate that at least 25 face threats to the habitat they occupy. The vulnerability of these occurrences to habitat modification or destruction is heightened by effects of small population size discussed above, reduced resilience to recover from acute demographic effects of habitat disturbances, and low potential for recolonization due to isolation from other occurrences. Based on available data, we consider approximately 85 percent of the species' extant populations to be small in number, and the cumulative impacts of multiple threats occur throughout a significant portion of the species range.

4.2   Conservation Factors

Short's bladderpod is listed as endangered in Indiana, Kentucky, and Tennessee. In Indiana this listing does not provide legal protection for the species; except for special consideration when planning government-funded projects. Additionally, the Indiana site is located on land owned by the IDNR where collection or damage to plants is prohibited (Homoya, pers. comm., March 2007).

The Kentucky Rare Plants Recognition Act, Kentucky Revised Statutes (KRS), chapter 146, section 600-619, directs the KSNPC to identify plants native to Kentucky that are in danger of extirpation within Kentucky and report every 4 years to the Governor and General Assembly on the conditions and needs of these endangered or threatened plants. This statute does not include any regulatory prohibitions of activities or direct protections for any species included in the list. On the contrary, it is expressly stated in KRS 146.615 that this list of endangered or threatened plants shall not obstruct or hinder any development or use of public or private land.

The Tennessee Rare Plant Protection and Conservation Act of 1985 (T.C.A. 11-26-201) authorizes TDEC to conduct investigations on species of rare plants throughout the state of Tennessee; maintain a listing of species of plants determined to be endangered, threatened, or of special concern within the state; and regulate the sale or export of endangered species via a licensing system. TDEC may use the list of threatened and special concern species when commenting on proposed public works projects in Tennessee, and the department shall encourage voluntary efforts to prevent the plants on this list from becoming endangered species. This authority shall not, however, be used to interfere with, delay, or impede any public works project.

Short's bladderpod was first identified as a federal candidate species in 1980 (45 FR 82480; December 15) and federally listed as endangered on September 2, 2014 (79 FR 44712). In the intervening years, there were limited conservation efforts directed towards reducing threats affecting the species and its habitat in Indiana and Kentucky.

Indiana DNR acquired the single Indiana occurrence from The Nature Conservancy. The IDNR controls competing vegetation by mowing along the roadside where Short's bladderpod occurs and attempts to stimulate germination and seedling recruitment with light soil disturbance. The species responded positively, at least in the short term, to this management (Homoya, pers. comm., December 2012).

In Kentucky, a Landowner Incentive Program grant was used to manage vegetation structure or control invasive species at two occurrences in 2005. The effort to control bush honeysuckle at Kentucky EO 19 provided at most a short-term benefit for Short's bladderpod, as bush honeysuckle is again well established at this site. During 2011, no Short's bladderpod plants could be found at this site, and the occurrence is presumed extirpated. The removal of cedar trees at Kentucky EO 23 appears to have positively affected habitat conditions for Short's bladderpod, as there were more than 100 plants observed at the site in 2015, 2017, and 2018. However, there were less than 100 flowering plants and seedlings at this site in 2019, potentially indicating a need for additional management to maintain or increase suitable habitat conditions needed to sustain a resilient population. The OKNP acquired lands to establish the Rockcress Hills State Nature Preserve, where Kentucky EO 22 is located and where the federally listed

endangered Braun's rockcress (listed as *Arabis perstellata*, but now recognized as *Boechera perstellata*) occurs. However, this occurrence is threatened by shading due to forest canopy development, no plants were observed at the site during 2019, continuing the downward trend in population numbers since 2011 when regular monitoring of the occurrence began (KNHP 2020). These conservation efforts have provided short-term benefits to three extant Short's bladderpod occurrences, but significant habitat threats remain across the species' range. Recent efforts to control invasive species at Kentucky sites have focused on EO 4 (Lane's Mill), EO18 (Cove Spring Park), EO 22 (Rockcress Hills State Nature Preserve), and EO 23 (Camp Pleasant) (Littlefield, pers. comm., March 2015).

In addition to these habitat conservation efforts, *ex situ* conservation and limited research into the species' reproductive ecology, population genetics, and shade tolerance have been initiated. The Missouri Botanical Garden has begun a rangewide population genetics study, seed ecology research, and is developing a protocol for propagating plants and growing them to reproductive maturity. MBG has also collected seeds from some Short's bladderpod occurrences for germplasm preservation and to use for reintroduction or augmentation efforts, should they become necessary, though more comprehensive seed banking efforts throughout the species range are warranted. Researchers at Tennessee Technological University are expanding upon preliminary research into the pollination ecology and mating system for Short's bladderpod, incorporating multiple sites in Kentucky and Tennessee.

With grants from the Service's Cooperative Endangered Species Conservation Fund (CESCF), the states of Kentucky and Tennessee have conducted surveys to locate additional occurrences of Short's bladderpod and have monitored existing occurrences. A considerable extent of potential habitat remains to be surveyed, nonetheless, both in the vicinity of some extant occurrences and in areas where new surveys are needed. Continued monitoring of occurrences tracked by NHPs may reveal the persistence of populations previously considered extirpated, while also providing valuable information about changes in population sizes and the amelioration or exacerbation of threats to populations. The Service will continue to work with state conservation agencies to seek opportunities to protect and manage habitats where Short's bladderpod occurs and to educate landowners about opportunities to contribute to recovery efforts for the species. As a result of federal listing, state conservation agencies received an incremental increase in funding through the CESCF to implement recovery projects, including monitoring, research, and habitat management.

4.3 Synopsis

The threats to Short's bladderpod from habitat destruction and modification are occurring throughout the entire range of the species. These threats include transportation right-of-way construction and maintenance; flooding and water level fluctuation; overstory shading; and competition with nonnative plant species. The population level impacts from these activities are expected to continue into the future, barring intervention for conservation purposes. The small sizes of many Short's bladderpod populations diminishes their resilience to these threats and increases the risks of inbreeding depression and decreased fitness. In addition to those threats explicitly discussed above, trash dumping, livestock grazing, and commercial and residential construction have been recognized as threats to habitat for this species, but there is little evidence that these are significant threats to extant occurrences. Existing threats may be exacerbated by

the effects of ongoing and future climate change, especially projected increases in temperature and increased frequency and severity of droughts in the Southeast and projected increases in flooding in the Midwest. Limited conservation efforts have been implemented for the species at a few sites, which produced short-term positive responses in the form of increased abundance and/or reproductive output. But, long-term commitments for managing threats to habitat are needed in order to produce stable or increasing population growth rates and maintain resilient populations.

5 Analysis of Future Conditions

Having assessed the historical and current conditions of Short's bladderpod populations to characterize the species status with respect to resiliency, representation, and redundancy, we now characterize expected future conditions for the species that could result from a range of scenarios. To do this, we examined risk factors discussed in the previous chapter to construct alternative scenarios, which vary with respect to combinations of conservation interventions that could be undertaken to reduce effects of stressors and the scale at which they would be implemented. The specific interventions assessed in the scenarios are developing conservation agreements/strategies, protecting populations on private lands, controlling invasive plants, reducing overstory shading, and augmenting populations. We prepared a strategy table (Table 8)

Table 8. Strategy table depicting alternative future scenarios for potential conservation interventions to recovery Short's bladderpod populations.

Scenarios	Develop Conservation Strategies and/or Agreements	Protect Resilient Populations on Private Lands	Control Invasive Plants & Reduce Overstory Shading	Augment Populations
One	Develop and implement a conservation strategy for occurrences on conservation lands, including Corps lands.	No long-term protection on private lands	Limited intervention on opportunistic basis	No augmentation
Two	Develop and implement conservation strategies/agreements for occurrences on Corps lands and lands managed by right-of-way managers (i.e., highway, railroad, utilities).	Protect one privately owned site each in Kentucky and Tennessee where >100 plants have been observed.	Treat all sites on protected lands for three consecutive years and then transition to less frequent maintenance.	In each ecoregion, augment one population where <100 individuals have been observed.
Three	Develop and implement conservation strategies/agreement for occurrences on Corps lands, lands managed by right-of-way managers, and all other sites on publicly owned or protected private lands (i.e., all protected sites).	Protect three privately owned sites each in Kentucky and Tennessee where >100 plants have been observed.	Prioritize 15 sites where management is needed. Treat for three consecutive years and then transition to less frequent maintenance.	In each county, augment one or more occurrences where <100 individuals have been observed.

to construct three alternative scenarios based on various combinations of these actions across a range of sites where Short's bladderpod populations occur. Each of the three scenarios is described below. The expected outcomes of these scenarios, with respect to changes in the resiliency, representation, and redundancy of Short's bladderpod populations, are discussed.

5.1   Scenario 1

Scenario 1 (Table 8, grey cells) focuses primarily on developing conservation strategies for occurrences located on State and Federal conservation lands, including those lands the Corps owns or holds easements on for flooding and access (Corps lands). Beyond focusing conservation efforts on these sites where Short's bladderpod is present on currently protected lands, management interventions to improve habitat by controlling invasive plants and reduce overstory shading would take place opportunistically on non-protected lands. No population augmentation would occur under Scenario 1.

There is one occurrence in Indiana and one in Kentucky that are located, at least in part, on State conservation lands. More than a thousand flowering plants were observed at the Indiana site in 1985 and thousands of seedlings in 2010, but no plants were seen in 2018 or 2019. In 2020, a few hundred plants were observed at the site, marking the first time since 2012 that the presence of more than 100 plants was documented. There were no plants observed at the Kentucky site in 2019, where abundance has fluctuated from a few plants to approximately 200, based on observations dating back to 1992. In Tennessee, there are 19 occurrences located on Corps lands (i.e., land owned in fee or where the Corps holds flood easements), where the most recent estimates of abundance ranged from 0 to 118 plants as of 2019. Some of these occurrences may be threatened by prolonged inundation and soil erosion along reaches of the Cumberland River that are impounded by Corps dam projects used for flood control and navigation. The Corps has been an active partner in pre-listing conservation efforts, assisting with boat access for surveys and monitoring efforts. Assessment of the impacts of prolonged inundation, both in natural populations and through ex-situ experiments, will be an important consideration for the development of adaptive management strategies. Given that the long-term viability of these populations on federal lands is essential to the recovery of Short's bladderpod, management strategies must be developed to restore and/or maintain favorable habitat conditions, including measures to control invasive plants and reduce overstory shading.

5.2   Scenario 2

Scenario 2 (Table 8, yellow cells) would expand the focus of conservation efforts to include developing conservation strategies and/or agreements for lands managed to maintain rights-of-way for transportation infrastructure and utilities, in addition to the protected lands that would be covered under Scenario 1. In addition, efforts would be made to protect one privately owned site each in Kentucky and Tennessee, where more than 100 plants have been observed in the recent past. Under this scenario, all sites on protected lands would receive management needed to control invasive plants and reduce overstory shading. Because of the need for repeated treatments early in such restoration efforts, especially for controlling invasive species, three consecutive years of treatments would be implemented to restore sites to a condition where less frequent treatments would be effective for maintaining desired conditions. Under this scenario, one occurrence on protected lands in each ecoregion would be augmented to improve demographic and genetic health of the Short's bladderpod population. This would include the

single site in the Wabash-Ohio Bottomlands ecoregion (Indiana), one site each in the Hills of the Bluegrass and Inner Bluegrass ecoregions (Kentucky), and one site each from the Outer Nashville Basin and Western Highland Rim ecoregions (Tennessee).

5.3   Scenario 3

This scenario (Table 8, blue cells) would be the most encompassing with respect to developing conservation strategies and/or agreements, by including all sites on publicly owned lands. Conservation strategies would be developed for three sites owned by local municipalities as well as any privately owned sites that become protected in the future, in addition to sites where this would have been done under Scenario 2. Scenario 3 also would involve the greatest effort to protect sites on private lands where relatively high levels of abundance have been observed in the recent past. This scenario would strategically prioritize sites where management would be undertaken to control invasive plants and reduce overstory shading, focusing on sites with opportunities to restore highly resilient populations on protected lands. Under this scenario, at least one occurrence in each of the 12 counties where Short's bladderpod is extant would be selected for augmentation. As with Scenario 2, this would involve the single site in Posey County, Indiana. In addition, four sites in Kentucky and seven sites in Tennessee would be selected for augmentation.

5.4   Anticipated Future Outcomes

Each of the future scenarios envisioned above would lead to improvements in the resiliency of some Short's bladderpod populations, with varying levels of improvement in redundancy of populations that would be resilient to demographic and environmental stochasticity within all units of representation in Kentucky and Tennessee. No scenario is predicted to result in changes in redundancy in Indiana (Wabash-Ohio Bottomlands ecoregion) but management would occur under all scenarios to maintain or improve resiliency of the sole occurrence in this area of representation. Thus, each scenario would improve the species overall viability (Table 9).

Scenario 1 would increase redundancy of occurrences with greater than 100 individuals (i.e., resilient occurrences) from the current number of 5 to 22 (Table 9). In Kentucky, one occurrence, located on State-owned lands in Franklin County (Hills of the Bluegrass ecoregion), would become resilient as a result of conservation efforts. Redundancy of resilient occurrences would increase in Tennessee from 3 to 9 in the Western Highland Rim and from 1 to 11 in the Outer Nashville Basin, by implementing a conservation strategy to improve resiliency of occurrences located on Corps lands.

Scenario 2 differs from Scenario 1 by providing redundancy of resilient occurrences in Kentucky and increasing redundancy of resilient occurrences to 26 across the range of Short's bladderpod. One occurrence on private lands in the Inner Bluegrass would be protected and conservation strategies would be implemented for three occurrences in rights-of-way in the Hills of the Bluegrass. The number of resilient occurrences would increase to five in Franklin County, with four of these occurrences in the Hills of the Bluegrass ecoregion, but redundancy of resilient occurrences would be lacking in the Inner Bluegrass. Redundancy of resilient occurrences in Tennessee would not increase but one currently resilient occurrence located on private lands would be protected, providing opportunities to manage habitat to increase resiliency of this occurrence.

Scenario 3 would further increase redundancy of resilient occurrences, as compared to the other two scenarios, resulting in 32 resilient occurrences across the species' range. Conservation strategies would be implemented to improve resiliency of occurrences at three sites on municipally owned lands, two in Kentucky and one in Tennessee, in addition to occurrences where resiliency would increase due to implementation of conservation strategies under Scenarios 1 and 2. Resiliency of 12 occurrences would be further increased by augmenting at least one occurrence in each county where Short's bladderpod is currently extant. In Kentucky, Scenario 3 would provide redundancy of resilient occurrences in the Inner Bluegrass ecoregion (total of three occurrences) and increase redundancy from four to seven resilient occurrences in the Hills of the Bluegrass. Redundancy of resilient occurrences would increase from five to seven in Franklin County but there would be only one occurrence each in Clark, Madison, and Woodford counties. In Tennessee, redundancy of resilient populations under Scenario 3 would increase from 4 to 5 in Cheatham County and from 9 to 10 in the Western Highland Rim ecoregion. While redundancy of resilient occurrences would not change in other Tennessee counties and the Outer Nashville Basin, resiliency of occurrences in these units of representation would increase due to augmentation to increase Short's bladderpod abundance.

Table 9. Numbers of occurrences with ≥100 individuals of Short's bladderpod, in each state, county, and EPA Level IV Ecoregion, that would be expected to result from three alternative conservation scenarios.

State	EPA Level IV Ecoregion	County	2020 Status		Number of Occurrences ≥ 100 individuals		
			Number of Occurrences	Number of Occurrences ≥ 100 Individuals	Scenario 1	Scenario 2	Scenario 3
Indiana	Wabash-Ohio Bottomlands	Posey	**1**	**1**	**1**	**1**	**1**
Kentucky	Inner Bluegrass	Clark	1	0	0	0	1
		Franklin	1	0	0	1	1
		Woodford	1	0	0	0	1
		Total	**3**	**0**	**0**	**1**	**3**
	Hills of the Bluegrass	Franklin	7	0	1	4	6
		Madison	1	0	0	0	1
		Total	**8**	**0**	**1**	**4**	**7**
Tennessee	Western Highland Rim	Cheatham	5	2	4	4	5
		Davidson/Cheatham	1	1	1	1	1
		Dickson	1	0	1	1	1
		Montgomery	3	0	3	3	3
		Total	**10**	**3**	**9**	**9**	**10**
	Outer Nashville Basin	Davidson	3	1	3	3	3
		Jackson	3	0	3	3	3
		Smith	2	0	2	2	2
		Trousdale	3	0	3	3	3
		Total	**11**	**1**	**11**	**11**	**11**
	Overall Total		**33**	**5**	**22**	**26**	**32**

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