Forbs: Foundation for Restoration of Monarch Butterflies, Other Pollinators, and Greater Sage-Grouse in the Western United States

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ABSTRACT: Monarch butterflies (*Danaus plexippus*), other pollinators, and Greater Sage-Grouse (*Centrocercus urophasianus*) are currently the focus of increased conservation efforts. Federal attention on these fauna is encouraging land managers to develop conservation strategies, often without corresponding financial resources. This could foster a myopic approach when allocating resources and setting restoration priorities, and at best, allow for inefficiencies in the usage of land management resources, or, at worst, pit one species (or suite of species, e.g., pollinators) against another (e.g., sage-grouse). Instead, investing holistically by linking conservation of these fauna may provide improved leverage of available resources and more benefit to the landscape. Fortunately, on the western US rangelands, these fauna can all benefit from restoration that increases the abundance and diversity of forbs. Establishing high density islands of outplanted forb seedlings may be a way to expedite restoration. Managers establishing forbs for pollinators (including monarchs) would further increase food availability for greater sage-grouse and vice versa. Adding milkweeds (*Asclepias* spp.) in appropriate areas to forb mixtures for restoration is warranted because they are excellent nectar sources for pollinators in general and the sole host for monarch larvae in particular. Here, we provide an overview of why forb species are keystone for monarch butterflies, other pollinators, and Greater Sage-Grouse and how seeding and outplanting seedlings of specific forbs are critical to restoration efforts.

Index terms: Centrocercus urophasianus, *Danaus plexippus*, forbs, native plants, wildflowers

INTRODUCTION

Diminishing populations of monarch butterflies (*Danaus plexippus* L.), other pollinators, and Greater Sage-Grouse (GRSG; *Centrocercus urophasianus* Bonaparte) are garnering the focus of conservation efforts in the United States. Recognizing the decline in pollinator health and the crucial role pollinators play in the nation's economy in supporting food production, President Barack Obama issued a memorandum in 2014 ordering creation of a "Federal Strategy to Promote the Health of Honey Bees and Other Pollinators" (WH 2014c). This initiated a flurry of activity within federal agencies to develop strategies, define research priorities, and implement best management practices based on the best currently available science. Activity was focused on federally managed lands with the purposeful intention of assisting private landowners (WH 2014a).

The rapid drop in the population of monarch butterflies has been well-documented (Brower et al. 2012; see Landis 2014), and degradation of overwintering sites, loss of breeding habitat, and extreme weather events have been discussed as causal agents (see Luna and Dumroese 2013). Because most monarch butterflies overwinter in Mexico and their summer range expands throughout the United States and into Canada, President Obama, President Peña Nieto of Mexico, and Canadian Prime Minister Stephen Harper issued a joint statement pledging that "[our nations] *will continue to collaborate in the protection of our region's biodiversity and to address other environmental challenges... Our governments will establish a working group to ensure the conservation of the Monarch butterfly, a species that symbolizes our association"* (WH 2014b). Similar to what happened in reaction to pollinator concerns, several federal responses followed that included conservation frameworks (e.g., USFS 2015) and a review by the US Fish and Wildlife Service (USFWS) of the butterfly's status under the Endangered Species Act (ESA) of 1973 (Federal Register 2014a). Although much attention is focused on the larger eastern population of monarch butterflies, our attention is on the western US population for two important reasons. First, these populations are not independent and integration occurs (Brower and Pyle 2004; Vandenbosch 2007), which likely contributes to improved genetic diversity and resilience. Second, their entire life cycle occurs in the West. Thus, US conservation efforts can concentrate on overwintering, breeding, and migrating habitats. Combined, these attributes (genetic interchange with the eastern population and annual life cycle entirely within the boundaries of the United States) suggest the western population is important for conservation focus in the context of conserving North American monarchs.

A suite of threats are impacting the sagebrush (*Artemisia* L.) biome. Anthropogenic activities leading to fragmentation and degradation (Connelly et al. 2011) are further driven through complex interactions of invasive annual grasses, encroachment by trees, altered fire cycles, grazing, climate change, energy development, and pesticides (Davies et al. 2011; Dumroese et al. 2015; Finch et al. 2015). The decades of chronic loss, fragmentation, and degradation within the sagebrush ecosystem have led to the acute potential problem of several sagebrush obligate wildlife species becoming threatened. Within this imperiled ecosystem (Noss et al. 1995) sage-grouse have become emblematic. During 2014, USFWS issued their final ruling on Gunnison Sage-Grouse (*Centrocercus minimus* J.R. Young, C.E. Braun, S.J. Oyler-McCance, J.R. Hupp & T.W. Quinn), determining it "threatened" under the ESA (Federal Register 2014b). Concurrently, USFWS was evaluating the status of GRSG under provisions of the ESA. Although the agency ruled in late 2015 that listing was not warranted (Federal Register 2015), this finding will be re-evaluated in five years. In part because of the potential repercussions on land management activities in the western United States, if GRSG (or other wildlife) is listed, the Secretary of the Department of the Interior (DOI) issued Order 3336 in January 2015 to proactively reduce sagebrush habitat loss due to fires spurred by invasion of annual grasses and to restore sagebrush communities (DOI 2015). Because of their need for large, contiguous areas of sagebrush, GRSG might serve as an umbrella species (Rowland et al. 2006); conserving GRSG habitat could simultaneously benefit other sagebrush obligate species, such as the pygmy rabbit (*Brachylagus idahoensis* Merriam), sagebrush vole (*Lemmiscus curtatus* Cope), pronghorn (*Antilocapra americana* Ord), sage sparrow (*Amphispiza belli* Cassin), and sage thrasher (*Oreoscoptes montanus* J.K. Townsend).

Given the explicit attention to monarchs, other pollinators, and sage-grouse, the potential to focus on species-specific measures is likely. Given that in the western United States, especially the Great Basin, these species overlap in habitat use, land managers may be able to, through more holistic approaches, leverage these important species-specific activities to achieve greater benefit for more species than can be accomplished working on a species-by-species approach (Dumroese et al. 2016). As noted by Davies et al. (2011), focusing on conserving ecosystems rather than single species affords opportunity to complete restoration work that subsequently reduces the need for future restoration interventions. For example, holistic pine forest restoration in the southeastern United States that included thinning and reintroduction of prescribed fire to maintain stand density and reduce occurrence of shrubs and hardwood trees resulted in improved habitat for Red-cockaded Woodpeckers (*Dendrocopos borealis* Vieillot), less incidence of bark beetles, and development of a rich herbaceous understory that supports more pollinators, including monarch butterflies (Rudolph et al. 2006a, 2006b; Hanula et al. 2015; Nowak et al. 2015). In fact, Davies et al. (2011) state that "*The sagebrush* (Artemisia) *ecosystem is a prime example of an area where many conservation objectives could be simultaneously achieved by developing a comprehensive ecosystem conservation plan*." This is particularly feasible in the western United States where much of the land is federally managed, and as we demonstrate below, an underlying component to successful restoration of monarchs, other pollinators, and sage-grouse is habitat rich in forbs (i.e., herbaceous plants without a persistent woody component). Given that resources for restoration are limited, land managers, by linking restoration efforts for monarchs, other pollinators, and GRSG with restoration of forbs, may be better positioned to leverage resources and show more broad scale benefit (Dumroese et al. 2016).

FORBS AND MONARCH BUTTERFLIES

Although monarch butterflies are classified as pollinators, these "charismatic microfauna" deserve separate consideration. Unlike bees that require nectar and pollen as a food source throughout their life cycle, adult butterflies visit flowers to obtain nectar, their primary energy source. Adult monarchs are floral generalists and have been observed "nectaring" on a wide variety of flowering plants. Nectar is high in sugars and contains other necessary food components, such as amino acids. Nectaring is particularly important during the late summer and fall when fall migratory monarchs are flying to their highly localized overwintering sites either in the mountains of Mexico (eastern population) or along the California Coast (western population). Monarchs convert the sugar to body fat that sustains them, not only during migration, but also during overwintering when most flowering plants are dormant (Alonso-Mejia et al. 1997).

Botanical information and range distributions on North America's approximately 75 native *Asclepias* L. species (milkweeds) can be reviewed in the PLANTS database (USDA NRCS 2015); almost half occur in the sagebrush biome (Table 1). Fourteen milkweed species can be found across the Great Basin and milkweeds can be found in all major plant communities (Borders et al. 2012). Monarch larvae are obligate feeders on milkweeds; all native milkweeds are perennial and potential food plants for larvae although some species are less desirable (Oberhauser and Solensky 2006). In the Great Basin, monarch larvae are known to feed on two widely distributed species: showy (*A. speciosa* Torr.) and narrowleaf (*A. fascicularis* Decne.) milkweed.

Milkweed phenology may be crucial to conserving monarch butterflies but has received little attention. In a southern California study (Wenner and Harris 1993), the first generation of monarchs coming off their overwinter sites focused on newly emerging *A. californica* Greene. This species starts growing with the onset of the winter rainy season and is one of the few native milkweeds available when monarchs depart their overwintering areas; oviposition was heavy and subsequent larvae feeding completely stripped plants of their leaves. Later, *A. fascicularis* appears. This suggests that incorporating a variety of milkweed species (as appropriate) into restoration projects has merit. A comparison of the phenology of these two *Asclepias* and monarch egg deployment is intriguing (Figure 1), but more research is required, especially where the range of monarchs and GRSG overlap.

Table 1. North American forb genera with a high proportion of their taxa found in the sagebrush biome.

Genus , authority	Percentage of taxa in sagebrush biome
Asclepias L.	46
Lomatium Raf.	39
Penstemon Schmidel	33
Astragalus L.	22
Eriogonum L.	17
Erigeron L.	14

Data compiled from searches of online Species of Concern (SOC) lists (CO, ID, MT, NV, OR, UT, WA, and WY) sorted by genus (e.g., *Asclepias* , *Erigeron* , *Lomatium* , etc.) and sage-steppe habitat through species summaries or field guides per state.

FORBS AND POLLINATORS

The meta-analysis by Winfree et al. (2009) found that anthropogenic disturbance negatively affected the abundance and species richness of wild, unmanaged bees. Habitat loss significantly reduced bee abundance and richness, but only when habitat was severely degraded; specialist pollinators and those that nest in cavities were particularly susceptible to extirpation (Burkle et al. 2013). In less degraded habitat occupied by invasive plant species, pollinators can persist because they also use those resources (Williams et al. 2011) and, thus, can respond favorably when invasive species are removed and native vegetation rebounds (Hanula et al. 2016). The complex interactions of pollinators with native and nonnative flora can, however, be positive or negative (Hanula et al. 2016), and therefore, any restoration activities should be considered within the context of specific ecosystem restoration objectives (Stanturf et al. 2014; Dumroese et al. 2015).

A rich flora of grasses and forbs, estimated at more than 5000 plant taxa, exists in the sagebrush biome (Dumroese et al. 2015). A small number of species-rich genera contain a significant percentage of rare taxa found in sagebrush habitats and account for significant totals of North American taxa per genus (Table 1). This floral diversity in turn supports robust insect diversity. At two large federal reserves in Idaho, efforts by Horning and Barr (1970) identified nearly 2100 species (19 orders; 1144 genera), and the summary by Hampton (2005) reports 1240 species (212 families; 747 genera) of insects in the sagebrush-dominated landscape. Because large expanses of structurally-diverse habitat are key to pollinator species richness (Spira 2001), no doubt many of these are native pollinators whose ecosystem services may not be supplanted by the European honey bee (*Apis mellifera* L.; Hymenoptera: Apidae) (Aslan et al. 2015).

Individual forb species in the sagebrush biome can support a wide variety of insect pollinators. For example, four congeners of *Chaenactis* DC. host 175 insect pollinator species representing 39 genera and six families (Cane et al. 2012), and *Lepidium papilliferum* (L.F. Hend.) A. Nelson & J.F. Macbr. hosts 25 families and five orders (Robertson and Klemash 2003). Suites of forb species within a single genus on a site can further enhance pollination service. For example, the diversity within *Astragalus* L. on a site was found to facilitate pollination of several co-occurring *Astragalus* species (Geer et al. 1995). And, at a broader scale, the abundance of bee species is positively correlated with overall herbaceous plant species diversity (Hanula et al. 2015). A single, high quality sagebrush site in southern Idaho, for example, hosted 12 species of bumble bees (*Bombus* L.; Hymenoptera: Apidae) (Cook et al. 2011), which are important pollinators of native

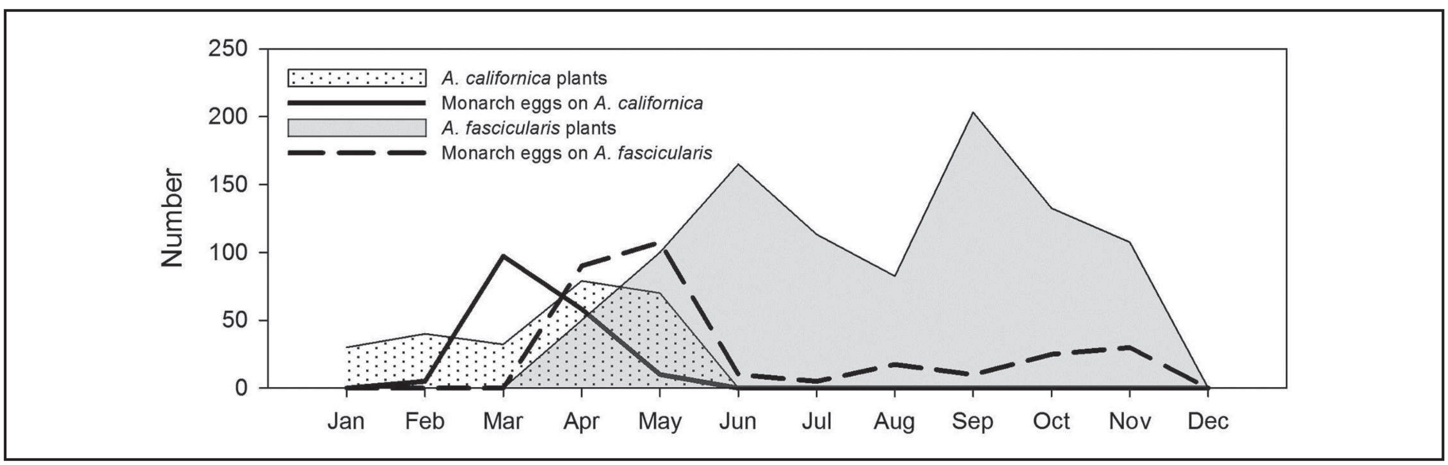

Figure 1. Early growing milkweeds (*Asclepias* species) are critical for the first generation of monarch butterflies that mate and lay eggs immediately after overwintering. For western monarchs, *A. californica* should be propagated more widely and outplanted near overwintering sites because it grows much earlier than the more common A. *fascicularis* (modified from Wenner and Harris 1993).

forbs (e.g., *Astragalus*; Green and Bohart 1975). This may be partially because of differences in temporal blooming of the forbs that, in turn, may foster temporal separation of pollinator species' activity, such as that observed for bumble bees in sagebrush habitat (Cook et al. 2011). Habitat connectivity is important for abundant and diverse bee communities (Steffan-Dewenter and Tscharntke 1999) and for effective pollination of specific plants, such as *L. papilliferum* (Robertson and Ulappa 2004).

FORBS AND SAGE-GROUSE

As mentioned above, the sagebrush biome has a diverse mosaic of sagebrush species, subspecies, and hybrids that is the foundation for even richer floras of grasses and forbs (see Dumroese et al. 2015). In turn, these diverse floras support a robust invertebrate community including pollinators, herbivores, predators, and detritivores. Together, the flora and invertebrate fauna provide the basis for survival of many obligate sagebrush fauna, especially GRSG. In particular, nesting hens, brooding females, and chicks consume a variety of annual and perennial forbs as well as the high-protein invertebrates those plants host (Wallestad et al. 1975; Drut et al. 1994b; Thompson et al. 2006; Ersch 2009).

The consumption of forbs varies with phenology of GRSG. The diet of pre-nesting hens may be, by weight, 18 to 50% forbs (Barnett and Crawford 1994). Within the first three weeks of development, GRSG chicks require insects to ensure survival and development (Johnson and Boyce 1990). In these first weeks, however, the shift toward greater forb consumption begins. Invertebrates comprise 52 to 60% of the diet of chicks less than seven days old (Klebenow and Gray 1968; Peterson 1970), but the diet of older chicks (greater than 2 to 3 weeks old) includes more herbaceous material. Overall, chick survival is positively correlated with greater forb and invertebrate consumption (Barnett and Crawford 1994; Drut et al. 1994a, 1994b; Thompson et al. 2006). This consumption is diverse; Drut et al. (1994b) documented 41 families of invertebrates and 34 genera of forbs (66 forb taxa noted by Dumroese et al. 2015). Forbs constitute more than 50% of the summer diet of juvenile and adult GRSG (Trueblood 1954; Klebenow and Gray 1968; Wallestad et al. 1975; Barnett 1992; Barnett and Crawford 1994; Connelly et al. 2000; Gregg et al. 2008). The suite of forbs consumed by GRSG progressively changes during the year in response to plant phenology (Klebenow and Gray 1968).

RESTORATION FOCUS ON FORBS

As described above, monarchs, other pollinators, and GRSG rely on forbs. Forb species diversity provides a broad temporal range in abundance and blooming that sustains these fauna throughout the growing season. High diversity forb communities within the sagebrush biome are necessary for GRSG survival and most likely support greater numbers of pollinators, and importantly, specialist pollinators. Thus, focusing on forbs during restoration work in the western United States offers the potential to achieve multiple management objectives that are currently of high priority: conserving pollinators and GRSG and restoring populations of monarch butterflies.

Assessment frameworks (Stiver et al. 2015), pollinator plant lists (e.g., Ogle et al. 2011b), and milkweed information (Borders et al. 2012) continue to highlight the need for forb species diversity. Unfortunately, despite efforts to research more forb species, particularly in the Great Basin (Dumroese et al. 2015), it appears restorationists have neither sufficient diversity of plant species available for use nor sufficient quantities of seeds for those that are available because current seeding practices are not accomplishing the goal of providing high diversity plant communities (Arkle et al. 2014). The reasons for this are myriad and beyond the scope of this paper; refer to Oldfield and Olwell (2015) and the National Seed Strategy (PCA 2015) for more information.

Introduced species can provide important resources for pollinators, monarch butterflies, and GRSG. For example, members of the Cichorieae with milky sap, both native (e.g., *Agoseris* spp., *Crepis* spp.) and introduced (e.g., *Lactuca serriola* L. *Tragopogon dubius* Scop., and *Taraxacum officinale* F.H. Wigg.), are readily consumed by GRSG and can comprise a substantial amount of their diet (e.g., Klebenow and Gray 1968; Wallestad et al. 1975; Barnett and Crawford 1994). Given more emphasis, however, on native species at the federal level (Johnson et al. 2010; PCA 2015), we will focus attention only on native species.

To explore the potential of incorporating multiple native forb species into restoration plantings to concurrently support monarch butterflies, other pollinators, and GRSG, we reviewed several species lists within three categories: "most likely" preferred by GRSG, known to be consumed by GRSG, and plants recommended for pollinators (i.e., pollinator plants) within the sagebrush biome. Stiver et al. (2015) list native (57 genera; 59 taxa) and nonnative forbs thought to be "most likely" preferred by GRSG. Native forbs (38 genera; 66 taxa) known to be consumed by GRSG were compiled by Dumroese et al. (2015). Five recommendations for pollinator plants for conservation activities in areas of current or estimated historical GRSG range (Ogle et al. 2011a, 2011b; Tilley et al. 2013; Pollinator Partnership n.d.a, n.d.b) yielded 69 native genera (130 taxa). See Figure 2 for ranges associated with the pollinator plant recommendations.

We compiled these lists into a single database to see which taxa appeared in multiple categories; this presented some challenges. For example, sometimes only genera were provided, some woody subshrubs (e.g., *Eriogonum* Michx.) were classified as forbs, and genera that included native and nonnative species were given without clarifying their status. For forbs known to be consumed by GRSG, some species were consumed often and in high quantities, whereas others were rarely utilized; often these rarely consumed species were not specified (e.g., Drut et al. 1994b). The distinction among annuals, biennials, and perennials is blurred when genera may have more than one life form. For genera that have been split (e.g., *Aster* L.), it was not clear what the appropriate new genus

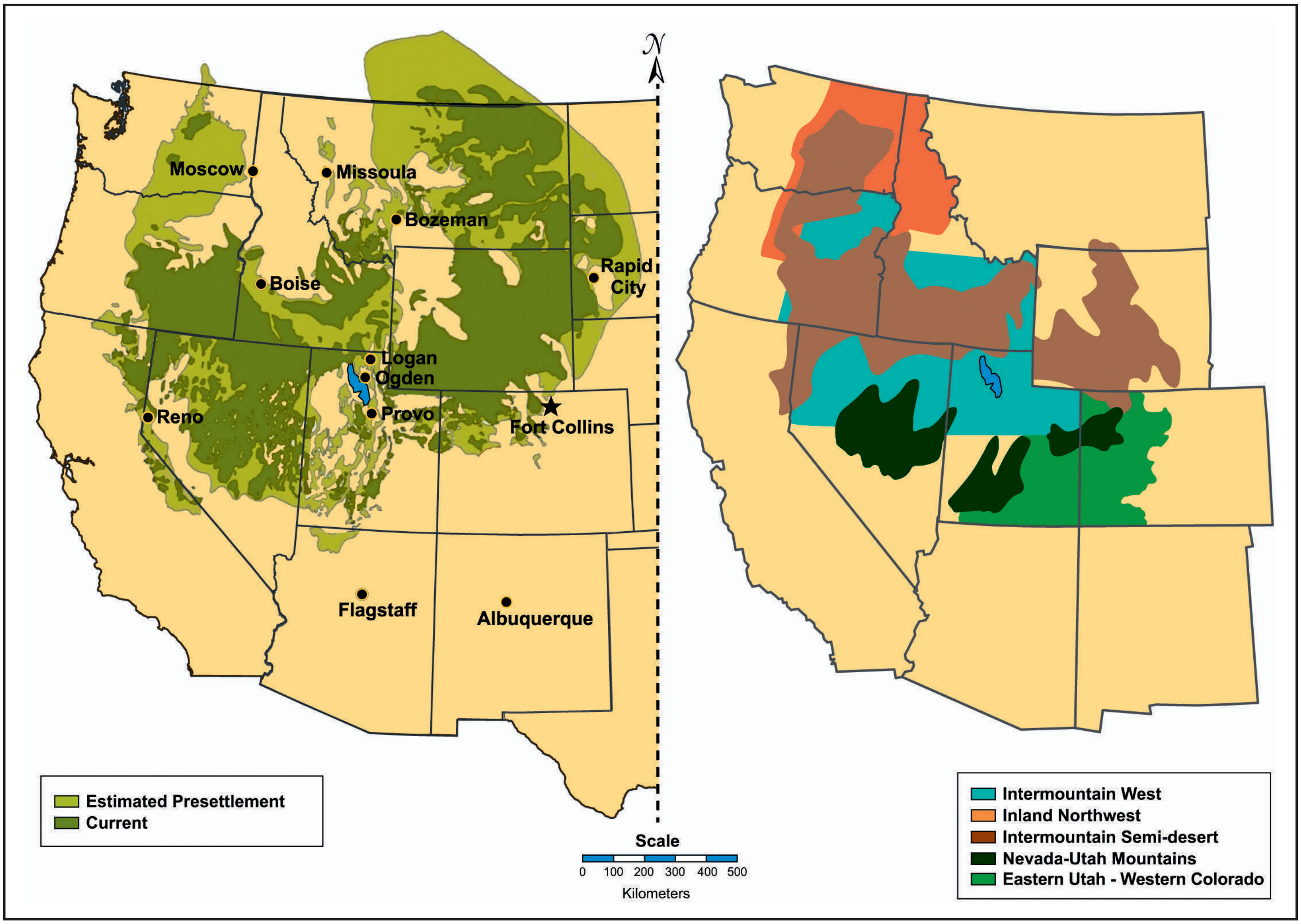

Figure 2. (Left) Estimated presettlement and current range of Greater Sage-Grouse (adapted from Schroeder et al. 2004). (Right) Ranges associated with forb recommendations for pollinators (adapted from Ogle et al. 2011a, 2011b; Tilley et al. 2013; Pollinator Partnership n.d.a, n.d.b).

should be but all references to *Aster* were classified as *Symphyotrichum* Nees given its predominance in GRSG habitat. And, finally, the available lists of forbs for pollinators were never intended to be inclusive of all pollinator plants within the area discussed (e.g., Tilley et al. 2013). Thus, we focused on genera, assuming that individual plant species within genera would share characteristics (i.e., "most likely" status or recommended for pollinators). Because some species are annuals, we counted *Eriogonum* as a forb despite many species having woody growth. Additionally, while *Salvia* L., *Yucca* L., and cacti are considered forbs in some lists, we did not include them as forbs. All *Artemisia* were considered shrubs or subshrubs. All species consumed by GRSG, regardless of amount, were included in the category. Genera that include annuals are shown in bold in Table 2.

Despite these limitations, we compiled 106 genera (225 taxa) of forbs. We found that 12 genera were common to the three categories and 14 additional genera were both "most likely" preferred by GRSG and recommended for pollinators (Table 2; Figure 3). Fewer commonalities were found among forbs known to be consumed by GRSG and the other two categories; this is not surprising given that fewer genera are confirmed in the diet of GRSG compared to the other categories (about half). In all, 40 genera were associated with two or more categories, with the Asteraceae and Fabaceae most represented (12 and 6 genera, respectively).

Within the 12 common genera, we noted 42 species (Table 3). Recommendations for pollinator plants were most specific (30 species; one taxa at the genus-only level). Forbs "most likely" preferred by GRSG were more generic (10 of 13 taxa at the genus-only level), which is understandable given the need for broad applicability of the Stiver et al. (2015) framework. The list of forbs consumed by GRSG was intermediate in detail (17 species; four taxa genus-only).

Annual forbs play an important role in the early development of chicks; abundance of *Microsteris gracilis* (Hook.) Greene var. *gracilis* and larvae of Lepidoptera were the only habitat variables related to positive brood survival in one study (Gregg and Crawford 2009). Annual forbs may also play important roles in restoring degraded sites. When planted on sites with a California Mediterranean

Table 2. Native forb genera of the sagebrush biome and their use classifications for Greater Sage-Grouse (GRSG) and pollinators. Either these genera, or species within them, were reported in the literature. Bold genera include annual plants. Double-line separates genera found in three categories from genera found only in two categories.

Genus, authority, family	"Most likely" preferred [1]	Consumed by GRSG [2]	Recommended for pollinators [3]
Astragalus L. Fabaceae [4]	X	X	X
Balsamorhiza Nutt. Asteraceae	X	X	X
Calochortus Pursh Liliaceae	X	X	X
Crepis L. Asteraceae	X	X	X
Erigeron L. Asteraceae	X	X	X
Eriogonum Michx. Polygonaceae	X	X	X
Geum L. Rosaceae	X	X	X
Lomatium Raf. Apiaceae	X	X	X
Mertensia Roth Boraginaceae	X	X	X
Symphyotrichum Nees Asteraceae	X	X	X
Trifolium L. Fabaceae	X	X	X
Vicia L. Fabaceae	X	X	X
Achillea L. Asteraceae [4,5]		X	X
Agoseris Raf. Asteraceae	X	X	
Antennaria Gaertn. Asteraceae		X	X
Arabis L. Brassicaceae	X	X	
Arenaria L. Caryophyllaceae	X	X	
Camassia Lindl. Liliaceae	X		X
Castilleja Mutis ex L. f. Scrophulariaceae		X	X
Chaenactis DC. Asteraceae	X		X
Cleome L. Capparaceae		X	X
Collinsia Nutt. Scrophulariaceae	X	X	
Comandra Nutt. Santalaceae	X		X
Dalea L. Fabaceae	X		X
Fritillaria L. Liliaceae	X	X	
Geranium L. Geraniaceae	X		X
Hedysarum L. Fabaceae [4,5]	X		X
Helianthella Torr. & A. Gray Asteraceae	X		X
Ipomopsis Michx. Polemoniaceae	X		X
Lathyrus L. Fabaceae	X		X
Lupinus L. Fabaceae		X	X
Machaeranthera Nees Asteraceae [5]		X	X
Mentzelia L. Loasaceae	X		X
Microseris D. Don Asteraceae	X	X	
Microsteris Greene Polemoniaceae	X	X	
Penstemon Schmidel Scrophulariaceae [5]	X		X
Phacelia Juss. Hydrophyllaceae	X		X
Phlox L. Polemoniaceae		X	X
Solidago L. Asteraceae	X		X
Sphaeralcea A. St.-Hil. Malvaceae [4]	X		X

[1] Stiver et al. (2015).

[2] Dumroese et al. (2015).

[3] Compiled from Ogle et al. (2011a, 2011b), Tilley et al. (2013), and Pollinator Partnership (n.d.a, n.d.b).

[4] Genus includes plant material releases from USDA Agricultural Research Service (fide T.A. Jones).

[5] Genus includes plant material releases from NRCS (USDA NRCS 2014).

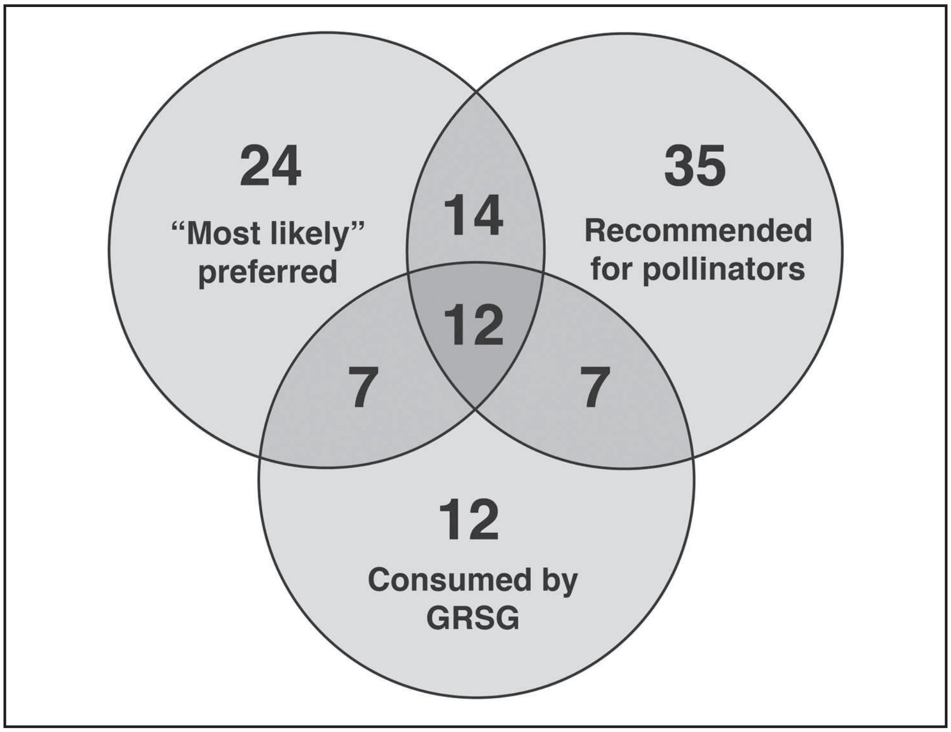

Figure 3. Venn diagram showing the relationship of genera noted "most likely" preferred by Greater Sage-Grouse (GRSG) (Stiver et al. 2015), consumed by GRSG (Dumroese et al. 2015), and/or recommended for pollinators (Ogle et al. 2011a, 2011b; Tilley et al. 2013; Pollinator Partnership n.d.a, n.d.b).

climate dominated by invasive species, annual native forbs remained abundant for several years (Seabloom et al. 2003). In Oregon, annual forbs as part of a multifaceted restoration project were thought to reduce weed establishment (Wold et al. 2011). Stiver et al. (2015) note 13 annual taxa "most likely" preferred and seven taxa of annual native forbs are known to be consumed by GRSG (*Blepharipappus scaber* Hook., *Collinsia* Nutt., *Gayophytum* A. Juss., *Grindelia squarrosa* (Pursh) Dunal, *Leptosiphon harknessii* (Curran) J.M. Porter & L.A. Johnson, *Microsteris gracilis* (Hook) Greene, and *M. gracilis* var. *gracilis*; Dumroese et al. 2015). Currently, however, native annual forb species were not represented in recommendations for pollinator plants that we reviewed (i.e., Ogle et al. 2011a, 2011b; Tilley et al. 2013; Pollinator Partnership n.d .a, n.d.b); these recommendations focused on perennials. This review suggests, however, that inclusion of annual species in restoration plans deserves more attention because (1) annual species occur with 13 genera "most likely" preferred by GRSG, (2) seven taxa are known to be consumed by GRSG, (3) little attention has been given them from a pollinator standpoint, and (4) some evidence exists that they can compete with invasive species on restoration sites. Fortunately, the Great Basin Native Plant Project (GBNPP), a joint project of the DOI Bureau of Land Management and the US Department of Agriculture Forest Service, has completed, or is currently conducting research on about 30 taxa of annual forbs (Dumroese et al. 2015).

This summary suggests opportunities to conserve pollinators and sage-grouse during restoration activities by using a foundation of forbs that fulfill multiple functions. This foundation can be augmented with additional species and life forms (annuals, perennials, shrubs) to increase the temporal occurrence of forage and flowers for GRSG and pollinators throughout the growing cycle. One important genus to augment is *Asclepias.* Besides being the obligate host for monarch larvae, *Asclepias* contain special nectaries that make them excellent nectar producers. In a recent evaluation of 43 species of native flowering perennials in the Pacific Northwest, *A. speciosa* attracted the greatest number of beneficial insects (fide Borders et al. 2012). While concerns about the toxicity of *Asclepias* have been raised, livestock poisoning caused by *Asclepias* typically only occurs when insufficient forage is available (Fleming et al. 1920). The widespread *Asclepias* occurring in potential GRSG habitat, *A. fascicularis* and *A. speciosa*, frequently grow in or near riparian zones (Ulev 2005; M.E. Horning, Geneticist, Deschutes National Forest, USDA Forest Service, pers. comm.). Although riparian habitats account for a mere fraction of the sagebrush landscape, they are important for increasing GRSG juvenile survival rates. These habitats provide late-season sources of forage for GRSG (Connelly et al. 2004), woody species, such as *Salix* L. and *Populus* L., provide early season pollen and/or nectar sources for pollinators, and migrating monarch butterflies often follow riparian corridors during migration (Dingle et al. 2005).

Selection of forbs for GRSG and pollinators should incorporate a temporal scheme (and perhaps floral color and floral shape schemes) to ensure season-long benefit. Finally, recent investigations are showing that some native forb species (even those often recommended) are less important than others to pollinators. For example, *Linum* L. and *Achillea* L. attract 12 to 50X fewer bees per 100 plants, respectively, than several other species of native forbs (Cane and Love 2016 this issue pps. 377-391). This does not necessarily negate them from restoration activities, but does provide more inference concerning the importance of deploying a wide variety of forb species to ensure that ecosystem functions are met.

Although we focus on forbs, some consideration of *Ericameria* Nutt. is relevant. Widespread throughout the western United States, communities of this shrub/subshrub, along with *Chrysothamnus* Nutt., yield more Lepidoptera larvae throughout May and June than *Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle communities (Ersch 2009), providing optimal food sources for GRSG during early brood rearing. Stiver et al. (2015) list it as "most likely" preferred by GRSG. Moreover, *Ericameria* bloom late in the growing season when most other flowering species are not, thus providing crucial food sources to pollinators; it is often recommended for that

Table 3. Additional details on the forb genera identified in Table 2 meeting all three categories for Greater Sage-Grouse (GRSG) and pollinator use. "X" indicates the specificity provided by the original sources.

Genus , *species* , authority	"Most likely" preferred [1]	Consumed by GRSG [2]	Recommended for pollinators [3]
Astragalus	X		
A. convallarius Greene		X	
A. curvicarpus (A. Heller) J.F. Macbr.		X	
A. filipes Torr. ex A. Gray [4]		X	X
A. lentiginosus Douglas ex Hook.		X	
A. obscurus S. Watson		X	
A. purshii Douglas ex Hook.		X	
Balsamorhiza		X	
B. careyana A. Gray			X
B. hookeri (Hook.) Nutt.	X		X
B. macrophylla Nutt.			X
B. sagittata (Pursh) Nutt.	X		X
Calochortus	X		
C. macrocarpus Douglas		X	
C. nuttallii Torr. & A. Gray			X
Crepis	X		
C. acuminata Nutt.		X	X
C. atribarba A. Heller			X
C. modocensis Greene		X	
C. occidentalis Nutt.			X
Erigeron	X		
E. corymbosus Nutt.		X	
E. engelmannii A. Nelson			X
E. filifolius (Hook.) Nutt.			X
E. linearis (Hook.) Piper			X
E. lonchophyllus Hook.		X	
E. pumilus Nutt.			X
E. speciosus (Lindl.) DC.			X
Eriogonum	X	X	
E. heracleoides Nutt.			X
E. niveum Douglas ex Benth.			X
E. sphaerocephalum Douglas ex Benth.			X
E. umbellatum Torr. [5]			X
Geum	X	X	
G. triflorum Pursh			X
Lomatium	X		
L. dissectum (Nutt.) Mathias & Constance [5]			X
			Continued

Table 3. (Continued)

Genus, *species*, authority	"Most likely" preferred [1]	Consumed by GRSG [2]	Recommended for pollinators [3]
Lomatium (Cont'd)	X		
L. grayi (J.M. Coult. & Rose) J.M. Coult. & Rose			X
L. macrocarpum (Nutt. ex Torr. & A. Gray) J.M. Coult. & Rose			X
L. nevadense (S. Watson) J.M. Coult. & Rose		X	
L. triternatum (Pursh) J.M. Coult. & Rose		X	X
Mertensia	X	X	
M. ciliata (James ex Torr.) G. Don			X
Symphyotrichum			
S. ascendens (Lindl.) G.L. Nesom			X
S. chilense (Nees) G.L. Nesom var. *chilense*	X		
S. laeve (L.) Á. Löve & D. Löve			X
S. spathulatum (Lindl.) G.L. Nesom			X
S. spathulatum (Lindl.) G.L. Nesom var. *spathulatum*		X	X
Trifolium	X		X
T. gymnocarpon Nutt.		X	
T. cyathiferum Lindl.		X	
Vicia	X		
V. americana Muhl. ex Willd.		X	X

[1] Stiver et al. (2015).

[2] Dumroese et al. (2015).

[3] Compiled from Ogle et al. (2011a, 2011b), Tilley et al. (2013), and Pollinator Partnership (n.d.a, n.d.b).

[4] Plant material release from USDA Agricultural Research Service (Johnson et al. 2008).

[5] Genecological study underway (J.B. St. Clair, personal communication).

purpose (Ogle et al. 2011a, 2011b; Tilley et al. 2013; Pollinator Partnership n.d.b) and would seem to be an important food source for migratory monarch butterflies. In addition, *Ericameria* provides winter forage for pronghorn, is an early seral species able to colonize disturbed sites, enhances nutrient cycling, serves as a nurse plant during establishment of other species, and resprouts after fire (Tirmenstein 1999); this is a desirable set of characteristics for restoring degraded land.

DEPLOYING FORBS ON THE LANDSCAPE

In the western United States, large tracts of land suffer from significantly altered disturbance regimes, including wildfire exacerbated by invasive grasses (D'Antonio and Vitousek 1992). In these situations, because land areas needing restoration are so large, direct seeding is the dominant form of restoration. Seed composition for direct seeding tends to be formulated based on available seeds and can include shrubs, grasses, and forbs that are native and nonnative. For treating large disturbed areas, direct seeding is seemingly the most economically plausible option, but success and recovery speed can be slow (Shaw et al. 2005). Increasingly, outplanted seedlings are becoming more appealing in these large-scale restoration efforts because of their better success rates (McAdoo et al. 2013); however, on a large scale, this method would be quite expensive. Alternatively, corridor, mosaic, or island planting strategies (Figure 4) may be employed to mitigate restoration costs while simultaneously offering enhanced restoration success (Rey Benayas et al. 2008).

Planting high diversity vegetation islands as a means of nucleation in restoration areas is not new (Stanturf et al. 2014). The topic of discussion has spanned rangeland, agricultural landscapes, forests, and tropical forests, to name a few (Longland and Bateman 2002; Rey Benayas et al. 2008; Holl et al. 2013). In some cases, this outplanting method has proven to be equally effective at increasing the abundance and diversity of tree recruitment

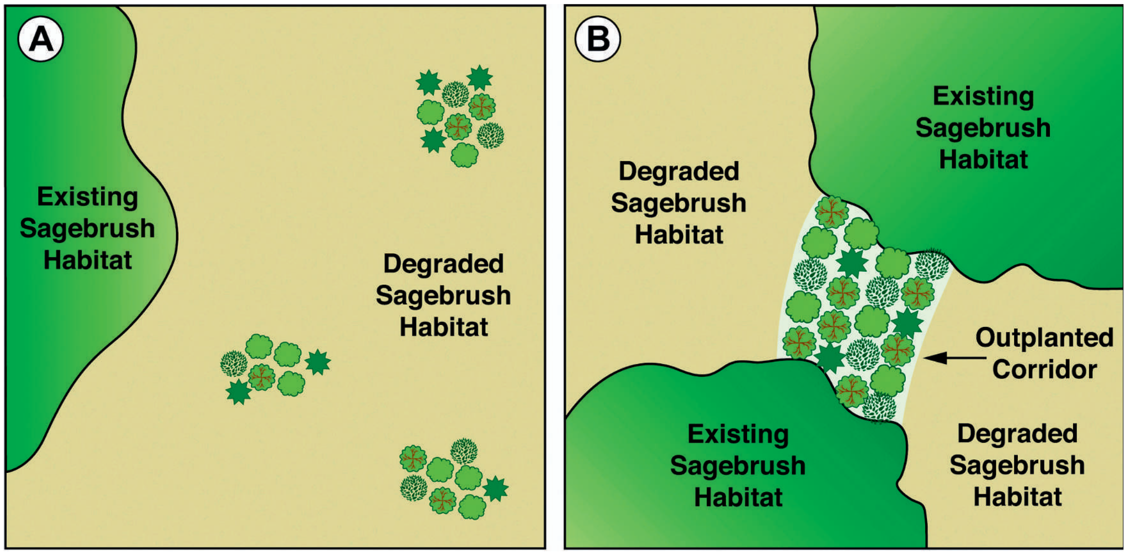

Figure 4. (A) Mosaic or island planting schemes using forbs may serve as nucleation points to aid restoration efforts in surrounding degraded habitat. (B) Similarly, outplanted corridors may link established habitats and also serve as nucleation points through areas of degradation (modified from Stanturf et al. 2014).

as plantation-style planting, better than passive restoration efforts, and can be substantially cheaper given the smaller areas treated (Holl et al. 2011; Corbin and Holl 2012). While this methodology has not been thoroughly tested in sagebrush rangelands, it offers the potential advantage of creating microsites that facilitate the survival and growth of multiple species, including forbs. In undisturbed semi-arid ecosystems, shrubs provide enough micro-environmental variation to influence surrounding atmospheric and edaphic properties, making them more favorable for seedling recruitment than interspatial zones (Davies et al. 2007; Boyd and Davies 2012). Postfire disturbances that leave intact shrub islands offer these microsite advantages as well as refugia for animal species that could provide future dispersal services (Longland and Bateman 2002).

Given that large-scale disturbance leaves vast amounts of land in need of restoration, and that outplanting seedlings across these areas at necessary densities may be economically unfeasible, island planting methods offer a viable alternative to direct seeding or passive restoration alone. Because nursery-produced seedlings, along with proper site preparation, can significantly increase outplanting survival and growth (Pinto et al. 2011; McAdoo et al. 2013; Davis et al. 2016), creating viable shrub and forb islands may be a feasible way to increase the restoration trajectory of degraded sites. Nurseries have the capacity to produce a wide variety of stocktypes and species that vary in age, size, and shape. Taking advantage of this, outplanted islands could use large nursery stock as shrub micro-environment engineers that, in turn, have potential to offer enhanced atmospheric and edaphic conditions for smaller, outplanted (or direct seeded) forbs and grasses. Using workhorse shrubs species (e.g., *Artemisia*, *Chrysothamnus*, *Ericameria*), along with forb species that offer maximal benefit to GRSG and pollinators (and other wildlife) (Figure 3), these island combination plantings have the potential to provide improved habitat sooner and serve as year-round food sources and sources for future propagule dispersal.

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