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Growing the state endemic, Oregon semaphoregrass (*Pleuropogon oregonus*): focus on a successful propagation and introduction program on Burns Paiute Tribal lands

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ABSTRACT

Oregon semaphoregrass (*Pleuropogon oregonus* Chase [Poaceae]) is a rare grass that occurs in only a handful of locations in eastern Oregon montane wet meadows, primarily on private lands. Propagation and outplanting methods have been developed over the past few decades to expand the geographic extent and to increase the number of plants by introductions in protected areas. The species rapidly increases through rhizomatous growth in a range of environmental conditions, provided sufficient moisture and nutrients are present, but is susceptible to some pests and pathogens. Over 2 decades, introductions with vegetative material have survived and increased in a mid-elevation meadow on Burns Paiute Tribal lands, a site relatively far from natural populations. Introductions in other areas have largely failed, however, likely because of unsuitable site environmental characteristics. Lessons learned from the successful propagation and outplanting program on Burns Paiute Tribal lands may be useful in future introductions, provided necessary site environmental attributes are identified.

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KEY WORDS

outplanting, rare species, vegetative propagation, wet meadows, Poaceae

NOMENCLATURE

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Oregon semaphoregrass (*Pleuropogon oregonus* Chase [Poaceae]) is a rare, wetland-associated grass (Figure 1) originally found in only 2 small population clusters approximately 370 km (230 mi) apart in Union and Lake Counties, eastern Oregon, USA (But and others 1985; Oregon Biodiversity Information Center 2019). This grass species is listed as threatened in the state of Oregon (Oregon Department of Agriculture 2018) and is globally ranked as critically imperiled (G1, NatureServe 2022). *Pleuropogon oregonus* is one of the rarest plant species in the state, with small, disjunct isolated populations, lack of formal protection in most sites, and multiple threats (NatureServe 2022). The species is rhizomatous and grows at high elevation (1079–1820 m [3540–5971 ft]) wet meadows with loamy, slightly acidic soils (Gisler and Meinke 2003). Most populations are located on private rangelands, typically grazed by cattle. Known from only 3 herbarium collections between 1886 and 1936, *P. oregonus* was rediscovered in 1979 in 1 of the original collection locations (But and others 1985). The species' relative vulnerability to extirpation prompted conservation efforts through propagation and outplanting into new locations after its rediscovery (reviewed by Groberg 2013). Considerable uncertainty remains regarding



Figure 1. The rare grass *P. oregonus* flowering in June 2022 from material propagated for introduction at the Burns Paiute Tribe Natural Resources (BPT DNR) greenhouse. Photo by Lori Ziegenhagen

aspects of the species' life history, tolerance to environmental stress, grazing, competition with introduced meadow grasses, and genetic variability (reviewed by Groberg 2013). However, ongoing efforts to establish introduced populations are yielding practical information on plant propagation and transplanting methods. In this technical article, we include a brief history of propagation efforts for this highly vulnerable grass, with a particular focus on the variety of approaches that have proved successful in the largest and oldest introduction site in Logan Valley, primarily on Burns Paiute Tribal lands east of Seneca in Grant County, Oregon.

HISTORY OF PROPAGATION AND INTRODUCTION EFFORTS

The Oregon Department of Agriculture (ODA) began the experimental cultivation of *P. oregonus* in the early 2000s, with a focus on conserving genetic variation in the 2 disparate Union and Lake County population clusters and avoiding outbreeding depression. Comparisons between the 2 clusters showed several character differences, such as average seed set and morphology; thus, most subsequent introduction efforts have used either Lake or Union County population sources (Gisler and Meinke 2001, 2003). Both Union and Lake County populations have high seed germination rates, with little evidence of dormancy, and increases with both wild-collected seed and rhizomatous tillers (individual shoots) were largely successful (Gisler and Meinke 2001). Flowering seems to require vernalization, or exposure to at least a mild winter period, as opposed to maintaining plants in a warm greenhouse setting (Gisler and Meinke 2001).

Initial propagation efforts with tillers from the Union County population in 2000 led to a successful introduction in 2002 on Burns Paiute Tribe land in Logan Valley (Figure 2), a large, high-elevation wet meadow located between the 2 known population clusters (122 km [76 mi] and 248 km [154 mi] from the nearest Union and Lake County populations, respectively). Success at this site continued in a series of outplanting efforts, primarily with Union County stock (with the exception of one unsuccessful 2010 plot with Lake County stock [Brown and others 2013]), over several years, resulting in thousands of tillers in several patches (Brown 2018). Plantings in Logan Valley in areas managed by Malheur National Forest have also been successful (Brown 2019). In 2018 the Burns Paiute Tribe Department of Natural Resources (BPT DNR) started an outplanting program involving collection, propagation, and annual plantings into new areas of Logan Valley BPT holdings.

In contrast to the relatively successful introduction in Logan Valley, other introduction sites with either Union or Lake County cluster stocks have been largely unsuccessful. Multiple introductions with Lake County stock in various sites near that population cluster over a period of several years with diverse

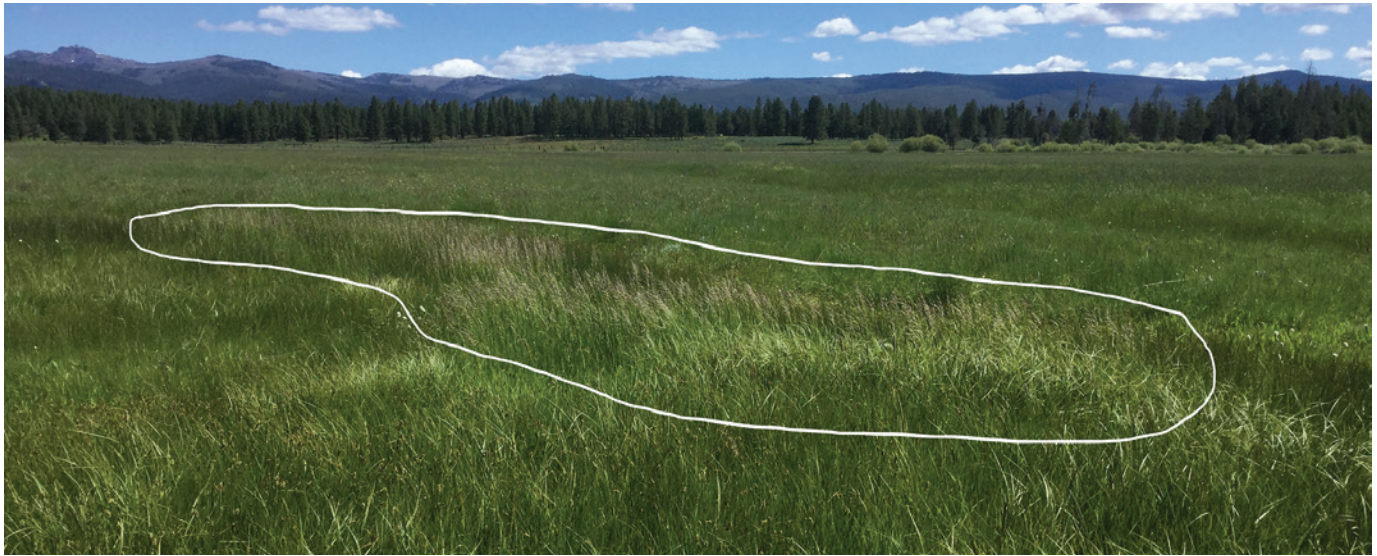


Figure 2. A >10-y-old patch of introduced *P. oregonus* in flower in June 2022 (center of the photo, outlined in white: one-sided inflorescences) on Burns Paiute Tribe land in Logan Valley, eastern Oregon. Photo by Stella Copeland

planting methods and site characteristics have disappeared or declined in the first few years (Brown and others 2011; Amsterry and Meinke 2015, 2016; Brown 2018). An attempted introduction in Union County with tillers from Lake, Union, and mixed original populations also failed to increase (Groberg 2013; Brown 2018). The current status of most introduction sites is unclear because of infrequent monitoring after initial lack of success. The poor outcomes based on the available monitoring results from several outplanting projects near natural populations suggest a need for a more robust understanding of the species establishment requirements.

While establishing new populations in sites other than Logan Valley has proved challenging, 2 decades of successful cultivation have led to propagation guidelines for additional outplanting efforts, which may be necessary if extensive *ex situ* conservation is required to preserve the species. Propagation and planting methods have been honed over many years by ODA, and lately, by BPT DNR; however, most of the methods have been included in reports that are not readily available. Here we present a summary of best propagation practices and outplanting methods based on current knowledge, with a focus on recent intensive efforts by BPT DNR in the most successful outplanted site thus far: Logan Valley.

COLLECTION TIMING AND METHODS

Since 2018, the BPT DNR has collected vegetative tillers from established *P. oregonus* plots at Logan Valley in mid-October through early November for subsequent cultivation under an ODA listed plant permit (legally required for working with state-listed plants). During this fall period, new young green tillers emerge near senesced tillers from the growing season (May–August). Material for greenhouse propagation is

collected by digging up approximately $0.25 \times 0.25 \times 0.25$ m ($0.82 \times 0.82 \times 0.82$ ft) sod clumps from well-established patches of *P. oregonus* and transporting them on ice in a cooler to avoid desiccation. Within 2 d of collection, clumps are carefully separated into smaller clumps of 5 to 10 cm (2–4 in) by loosening the soil with water and then planted in saturated potting soil in 265 l (70 gal) round end stock tanks (Behlen Manufacturing, Columbus, Nebraska). In previous propagation efforts, ODA used similar methods but collected tillers in the spring, summer, and fall (Brown and others 2011, 2014; Groberg 2013).

For seed collection, BPT DNR collects inflorescences from established *P. oregonus* plots at Logan Valley from August to October, but seed could likely be collected earlier. For greenhouse-grown plants, BPT DNR collects inflorescences in June to July, which is when ODA has collected inflorescences from the natural populations (Gisler and Meinke 2001). Prior to planting in the fall or spring, BPT DNR manually cleans the seeds (caryopses) (Figure 3) by removing other floret structures, including the palea, lemma, and glumes, and stores the seeds in dry envelopes. Envelopes are stored at room temperature but not in a carefully controlled environment.

PROPAGATION METHODS

BPT DNR has used various containers for cultivation. The most successful container is a 265 l (70 gal) round end stock tub (1.8 m [5.9 ft] length $\times$ 0.6 m [2.0 ft] width $\times$ 0.3 m [1.0 ft] deep). The large size and depth of these containers maintains high soil moisture and allows for plenty of room for rhizomatous growth to produce new tillers. Tubs are filled approximately 17.8 to 22.9 cm (7–9 in) deep with Metro-Mix 840 potting mix (Sun Gro Horticulture, Agawam, Massachusetts).



Figure 3. *Pleuropogon oregonus* seeds (caryopses; scale is mm). Photo by Lori Ziegenhagen

ODA also used various pot sizes and types and soil media in their propagation efforts. ODA generally used large, plastic wading pools for propagation (Brown and others 2012b; Brown 2018) after trying various other approaches, as this method allowed for unrestricted tiller expansion compared to smaller containers (Gisler and Meinke 2001). After testing various planting medium combinations with sand, loam, and potting soils (Currin and Meinke 2006), ODA used potting soil almost exclusively for cultivation (Gisler and Meinke 2001; Brown 2018). ODA ultimately determined that the type of growing medium was not as important as keeping the media well-watered (Currin and Meinke 2006).

The BPT DNR has grown *P. oregonus* in both a non-climate-controlled greenhouse and outside in ambient temperatures in

Burns, Oregon (Table 1). The greenhouse has become the primary method for BPT DNR because the longer growing season (with warmer temperatures fall through spring) leads to more tiller production. Summer temperatures are slightly dampened with fans and open doors, and a heater has sometimes been used in the winter. ODA primarily grew plants outside in Corvallis, Oregon, after some experimentation with growing plants under lights (Gisler and Meinke 2001; Brown and others 2012b; Brown 2018). Corvallis has a much milder climate compared to Logan Valley or the natural population areas (National Centers for Environmental Information 2022), which likely led to a much longer growing season when the plants were grown outside rather than in the natural population clusters or in the BPT greenhouse in Burns.

BPT DNR waters the tubs as needed to keep the soil moist a few cm below surface level, typically fully saturating the tubs every few watering events. BPT DNR waters at least once every 1 to 3 wk in the summer months but far less often in the cooler months. ODA watered regularly to maintain subsurface moisture, with more frequent watering in the summer than in the cooler months, to allow plants to senesce (Gisler and Meinke 2001; Groberg 2013). ODA drilled drainage holes at approximately 2 cm (0.8 in) above or below the soil line to prevent excess pooling (Gisler and Meinke 2001), whereas BPT DNR drilled drainage holes a few centimeters below the soil line.

BPT DNR fertilizes each tub using GROW 7-9-5 (N:P:K) fertilizer (DynaGro, Richmond, California) at a rate of 29.6 ml (2 tbsp) per 7.6 l (2 gal) of water. BPT DNR used various fertilizer application frequencies, but most recently applied this fertilizer mixture approximately once every 2 wk from June to August. ODA used various fertilizers and frequencies with success (Brown and others 2008; Brown and others 2013; Groberg

TABLE 1

Mean climate annual and seasonal temperature and precipitation for weather stations near the natural population clusters in Lakeview (Lake County) and Union (Union County), introduced location area in Logan Valley, and propagation locations in Burns and Corvallis, Oregon (station codes listed, US Climate Normals, 1991–2020, NCEI, NOAA, 2022).

		Lakeview USC00354670	Union USC00358746	Logan Valley (Seneca) USC00357675	Burns Airport USW00094185	Corvallis OSU USC00351862
Temperature °C (°F)	Annual	8.3 (47.0)	9.4 (49.0)	4.7 (40.5)	7.8 (46.0)	11.6 (52.9)
	Winter	−0.6 (30.9)	0.8 (33.4)	−4.1 (24.6)	−2.3 (27.8)	5.2 (41.4)
	Spring	6.8 (44.3)	8.7 (47.6)	4.2 (39.6)	7.3 (45.1)	10.6 (51.0)
	Summer	18.3 (65.0)	18.8 (65.8)	14.1 (57.3)	18.3 (64.9)	18.6 (65.4)
	Fall	8.9 (48.0)	9.6 (49.2)	4.7 (40.5)	7.8 (46.0)	12.2 (54.0)
Precipitation mm (in)	Annual	366.3 (14.4)	374.9 (14.8)	347.2 (13.7)	264.4 (10.4)	1093.2 (43.0)
	Winter	141.0 (5.6)	84.8 (3.3)	112.0 (4.4)	96.5 (3.8)	481.8 (19.0)
	Spring	109.0 (4.3)	137.4 (5.4)	104.6 (4.1)	80.5 (3.2)	268.0 (10.6)
	Summer	34.0 (1.3)	137.4 (2.6)	53.3 (2.1)	32.3 (1.3)	52.6 (2.1)
	Fall	82.3 (3.2)	85.9 (3.4)	77.2 (3.0)	55.1 (2.2)	290.8 (11.5)

2013; Brown 2018); however, fertilizer types and rates were not formally compared.

CONTROLLING PESTS AND WEEDS

Collecting tillers from dense patches of *P. oregonus* limits the introduction of other plant species to the tubs, but low densities of other species can make it into the tubs and weed seeds can blow into the tubs during the growing season. *Pleuropogon oregonus* is also susceptible to fungal pathogens and aphids. BPT DNR manually weeded tubs as needed. ODA manually weeded and has also applied broadleaf herbicide Ortho Weed B Gone (The Scotts Company, Marysville, Ohio) (Gisler and Meinke 2001; Brown and others 2011).

BPT DNR has attempted with little success to control aphids and fungi with hydrogen peroxide, sulfur, pyrethrin (Insect, Mite & Disease 3-IN-1 Ortho, The ORTHO Group, Marysville, Ohio), and neem oil-based (Fungicide3, Garden Safe LLC, Bainbridge Island, Washington) solutions. BPT DNR also tried to remove aphids by hand and with water. USDA ARS (co-authors) working with BPT DNR have had success controlling aphids by saturating leaves and soil surface once a week with a dilute hydrogen peroxide mixture (5 ml [0.17 oz] of 3%

hydrogen peroxide to 240 ml [8.12 oz] water) and avoiding watering the same day (to avoid rinsing off the solution). In contrast, USDA ARS had little success controlling aphids with a soap solution (10–15 drops pure castile soap per 237 ml [8 oz] of water) and noticed the soap solution appeared to cause leaf damage. ODA used the pesticide resmethrin, removal by hand, and soap spray to control aphid infestations (Gisler and Meinke 2001; Brown 2018). ODA also applied Bt (*Bacillus thuringiensis*) pesticide to control cutworms (Noctuidae larvae) and controlled various fungi (*Alternaria* spp., *Cladosporium* spp., *Puccinia* spp., and *Septoria* spp.) with fungicide applications (Strike 50 WDG, OHP Inc, Mainland, Pennsylvania), removing dead vegetation, limiting cross contamination between pools, and limiting wetting of the foliage (Brown 2018). One of the reasons ODA grew *P. oregonus* outside, instead of the more humid greenhouse, was to limit fungus infection (Currin and Meinke 2006).

PLANTING MATERIAL INCREASE

Pleuropogon oregonus increases rapidly via rhizomatous growth with various propagation methods (Figure 4, Figure 5). For 3 consecutive years, BPT DNR propagation efforts produced final



Figure 4. Clonal expansion over several months from 14 January to 27 October 2019 in 2 tubs of *P. oregonus* at the BPT DNR greenhouse in Burns, Oregon. Photos by Carter Crouch

tiller numbers 14.0 to 15.2 times the original planted numbers each year (Figure 5). BPT DNR typically sees little growth over the winter, significant growth in the spring and early summer, a dieback in summer, and new tiller growth in the late summer and early fall prior to planting. The potential of this species to expand through cultivation was first documented by ODA who recorded an increase from 60 tillers to more than 2000 tillers for Union County stock and an increase from 60 tillers to approximately 750 tillers for Lake County stock from summer 2000 to summer 2001 (Gisler and Meinke 2001; Brown and others 2011). ODA has continued to document this expansion potential through subsequent work (Brown and others 2011, 2012b, 2013; Brown 2019).

BPT DNR has also documented tiller expansion from seed-grown plants, suggesting that propagation from seed is an option for outplanting programs. While BPT DNR did not collect germination or seedling survival data, they were able to produce more tillers than the number of seeds planted. BPT DNR planted a total of 234 seeds in various pots from 13 November 2018 to 10 April 2019 and outplanted the resulting 765 tillers on 28 October 2019. BPT DNR planted 1024 seeds in a tub on 8 April 2020 and outplanted 1089 tillers on 23 October 2020. ODA estimated germination between 70 and 90% regardless of the germination treatments used, with Union County seed, receiving no treatment, having a germination rate of 86.7% (Gisler and Meinke 2001) and 48.4% (Brown 2018) in separate studies. ODA estimated 4 mo seedling survival for Union County seed

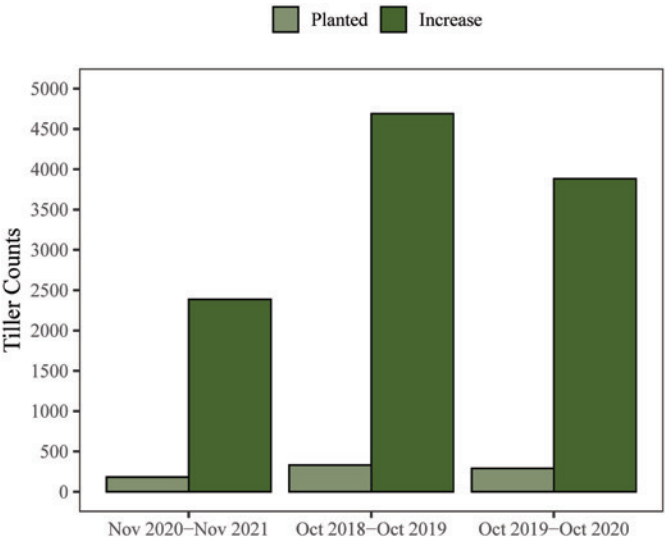


Figure 5. Clonal expansion from wild-collected tillers after 1 growing season in tubs located in greenhouses and outside the Burns Paiute Tribe Natural Resources Office. Note that tiller counts are approximate, as some tillers are lost when digging up and splitting clumps at collection and planting. Original tillers tend to senesce within months of planting, meaning that tillers counted after 1 y are likely to be new tillers. This means that the final number of tillers were 15.2, 14.3, and 14.0 times the original planted tillers for the 2018, 2019, and 2020 collection years, respectively.

at 86% and documented an average of 5.2 (range 0–9) new tillers for each seedling over that period (Gisler and Meinke 2001).

PLANTING METHODS

New outplanting areas within the BPT Logan Valley area are selected based on the following criteria: They must be low areas, ditches, or drainages with some bare ground, dominated by *Carex* and *Juncus* species, and not in flowing water when planted (October–November). A shovel is used to dig up large soil blocks of tillers from the planted tubs the day before planting. Blocks are rinsed with a hose or by dipping into buckets of water and are then carefully separated into square clumps of 5 to 10 cm (2–4 in) (Figure 6). These smaller clumps are put in plastic bags and placed on ice in a cooler until planted (Figure 7). Individual clumps are planted by making slits into the soil with a shovel (soil is not removed), placing the clump within the soil slit, and repacking soil around the slit, taking care to cover all roots and attached potting soil with native soil.



Figure 6. Smaller clump of *P. oregonus* with most of the potting soil rinsed out. Note that the red stems are below the soil surface in grow-out conditions, and transplant clumps should be planted with the red stems buried. Photo by Carter Crouch



Figure 7. Smaller clumps of *P. oregonus* bagged up and ready to be placed in a cooler for transplant. Placing the clumps in a bag facing the same way limits damage to the vegetation and allows for more accurate counting of tillers while planting. Photo by Carter Crouch

Individual tillers are counted as they are planted to track how many tillers are planted in each plot. After planting, tillers are watered with approximately 9.5 l (2.5 gal) of water per plot.

In 2019, volunteer groups and staff planted tillers into square and rectangular plots with various dimensions (0.6 × 0.6 m [2.0 × 2.0 ft], 0.6 × 0.9 m [2.0 × 3.0 ft], 0.6 × 1.2 m [2.0 × 4.0 ft]). Volunteers and staff planted 152 to 493 tillers in each plot. In 2020 and 2021, BPT DNR switched to using 0.5 × 0.5 m (1.6 × 1.6 ft) plots to allow BPT DNR to plant into more areas and to facilitate rapid monitoring. In both 2020 and 2021, volunteers and BPT DNR staff planted 113 to 264 tillers (density 452 [42] to 1056 [98] tillers/m² [ft²]) in each plot (except for 3 plots with 44 to 56 tillers/plot), spreading out clumps as described above throughout the plot. PVC pipe is used to mark the corners of all plots to assist with future efforts to monitor planting increases (Figure 8).

In 2002, ODA, in coordination with BPT, planted 3 sites with 10 plots per site. Each plot received 8 plugs (clumps) with an average of 7.2 tillers/plug (Amsberry and Meinke 2004). From 2009 to 2012, ODA in coordination with BPT DNR added 20 new plots (4 to 6 plots/y) with approximately 5000 tillers total, and plots received between approximately 100 and 700 tillers (Brown and others 2012a, 2012b, 2014). In 2013, approximately 9000 to 12,000 tillers were added near and around 6 previously established plots (Amsberry and Meinke 2015). In 2017, ODA added 6 plots to Tribal property and 13 plots on the Malheur National Forest in Logan Valley. ODA outplanted tillers from September to October in all years (Gisler and Meinke 2001; Brown and others 2012a, 2012b, 2014; Brown 2019), usually in 1 m² (10.8 ft²) plots with a PVC post to mark the plot center (Amsberry and Meinke 2004; Brown and others 2012a). However, ODA also planted alongside channels, not following a strict shape, with PVC posts at the ends (Brown and others 2012b), and they added clumps of tillers near previously established plots (Amsberry and Meinke 2015). ODA planted small groups of tillers in holes or slits and often watered tillers



Figure 8. Watering planted *P. oregonus* tiller clumps. Bright green tillers are *P. oregonus* while the dried vegetation is an unplanted *Carex* species. Plots are placed in areas with some bare ground, but this plot has more bare ground than most plots. Volunteers and staff try to space out clumps and tillers across the plot. PVC is added to corners to aid in future monitoring. Photo by Thomas Gilg

after planting (Brown and others 2012b; Amsberry and Meinke 2015). Competing vegetation was removed for some of the Lake County plantings, but not for the Logan Valley plantings (Amsberry and Meinke 2004).

ESTABLISHMENT

The individual plots established at Logan Valley between 2002 and 2018 are difficult to track through time. Many of the plots were planted near each other, subsequent plantings were added to previously established plots, plots were grouped inconsistently during tiller monitoring and counts, plot markers have been lost over time, and tillers have expanded from the original planting areas. However, it appears that many of the plots planted between 2002 and 2018 have been successful and self-sustaining. An estimated 14,728 to 18,228 tillers were planted in Logan Valley between 2002 and 2013, which yielded 9339 tillers (8088 vegetative and 1251 reproductive) in the last full count in 2018. Many of the plots planted in 2002 still had both vegetative tillers and inflorescences in 2021. A few of the most successful plots showed promising results early on and were supplemented with more tillers in later plantings. Other plots have been less successful. One cluster of plots planted in 2002 were inundated by an upstream beaver dam and appears to have been lost (Brown and others 2011, 2012a, 2012b). One microsite area within Logan Valley (planted in 2009) also appears to have been unsuccessful for unclear reasons (Brown and others 2012b, 2013, 2014). Additional plots planted in 2017 in Logan Valley were less successful, with tillers present in only 2 of 6 plots the year following planting (2018, ODA unpublished data); long-term persistence is unknown due to difficulty relocating the plots. Outplant efforts in 2017 on Forest Service property, near the BPT Logan Valley sites, were mostly successful, with tillers in most plots the year following planting (11 of 13 plots in 2018) and 4 y post-planting (10 of 13

plots in 2021). Of the 19 plots planted by volunteers and BPT DNR staff in 2019, 11 (57.8%) still had tillers in them in both the first and second growing season following planting. Of the 28 plots planted in 2020, 22 (78.6%) still had tillers in them in the first growing season following planting. While most plots had at least some tillers present in the years following planting, there were many fewer tillers than had been planted. In 2019, volunteers and BPT DNR staff planted a total of 5784 tillers, with 395 tillers (6.8%) counted the following growing season (2020), and 209 tillers (3.6%) remaining after 2 y (2021). Volunteers and BPT DNR staff planted a total of 4931 tillers in 2020, with 479 tillers (9.7%) remaining in the following (2021) growing season.

CONCLUSIONS

Pleuropogon oregonus does not appear to have stringent cultivation needs based on successful propagation efforts with a variety of containers, soil media, fertilization rates, temperatures, and lighting. Outstanding research gaps with implications for future introduction efforts remain, however. For instance, identifying the environmental factors that influence establishment at Logan Valley could assist in locating future introduction sites with higher likelihood of successful establishment. Research into the genetic variation in both the natural and the introduced populations is also needed, given the frequent reliance on clonal expansion for introduction efforts using limited collections from small, natural populations. While establishing self-sustaining introduced populations of *P. oregonus* has proved challenging, the success at Logan Valley over nearly 20 y, with the methods described here, is a promising sign and illustrates a potential path forward for future introduction efforts.

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