

# Restoration Notes

Restoration Notes have been a distinguishing feature of *Ecological Restoration* for more than 25 years. This section is geared toward introducing innovative research, tools, technologies, programs, and ideas, as well as providing short-term research results and updates on ongoing efforts. Please direct submissions and inquiries to the editorial staff (ERjournal@aesop.rutgers.edu).

## Can Fertilizers Increase the Seed Yield of Two Native Herb Species in the Subarctic? Implications for Wild Seed Collection

Brittany Rantala-Sykes (corresponding author: Department of Biology, Vale Living with Lakes Centre, Laurentian University, Sudbury, Ontario, P3E 2C6, Canada, bgrantala.sykes@gmail.com) and Daniel Campbell (School of the Environment, Vale Living with Lakes Centre, Laurentian University, Sudbury, Ontario, P3E 2C6, Canada).

Local native seed is collected from the wild to restore disturbed land when local commercial seed sources are unavailable. What if wild local populations have low seed output? Low seed yields can result from: 1) pollen limitation and pollinator scarcities, especially for self-incompatible species (Burd 1994, Ashman et al. 2004); and 2) abiotic limitations, including resources such as light, water, and nutrients (Stephenson 1981). Pollen limitation and climate are difficult to circumvent. Managers may more easily manipulate certain resources, such as nutrients. In boreal and arctic biomes, N and P are the most commonly limiting nutrients (Shaver and Chapin 1995, Weintraub 2011), but fertilization studies have found variable and species-specific responses on flowering or seed output (Shaver and Chapin 1995, Grainger and Turkington 2013, Petraglia et al. 2013). In this study, we posed the question whether fertilizer addition in a natural subarctic ecosystem over two growing seasons could increase the seed yields for desirable restoration species.

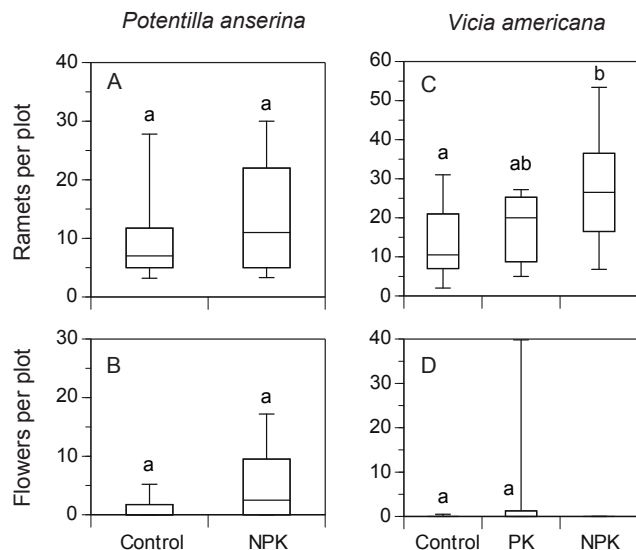
We conducted our study in north-central Canada along a 1.5-km south-facing section of the Attawapiskat River floodplain (52.88° N, 83.91° W, 83 m elevation). The soils were calcareous, alkaline and poorly-developed, with low N and P within primary rooting zones (Garrah 2013). The vegetation was open as a result of annual river ice damage, dominated by herbs and scattered shrubs. We selected two perennial herbs, *Potentilla anserina* (silverweed), a spreading ground cover, and *Vicia americana* (American vetch), a N-fixing legume. Both species are self-incompatible and insect-pollinated (Gunn and Kluve 1976, Eriksson 1987,

Miyaniishi et al. 1991) and are regionally common but have low seed output. We hypothesized that fertilization would increase flowering, seed set, and total seed yield after two seasons and that *V. americana* would not need N amendment because it is a N-fixing species.

For each species, we set up ten blocks of 1-m<sup>2</sup> plots, containing one plant of either *P. anserina* or *V. americana*. In June 2015 and again in June 2016, we applied two treatments (control and NPK fertilization) to *P. anserina* and three treatments (control, PK, and NPK fertilization) to *V. americana*. We used urea [CO(NH<sub>2</sub>)<sub>2</sub>], superphosphate [Ca(H<sub>2</sub>PO<sub>4</sub>)<sub>2</sub>] and potash [KCl (95%) NaCl (5%)] at a rate that contributed 4 g m<sup>-2</sup> each of N, P, and K. We watered plots after fertilization. In August 2016, we assessed: (i) the number of ramets; (ii) the number of flowers per ramet; and (iii) the number of flowers per plot. We tested for significant differences among treatments for each dependent variable using a permutation test with 10,000 random shuffles, using Resampling Stats® (Excel add-in v. 4.0, Resampling Stats, Arlington, Virginia). For *P. anserina*, we resampled the difference between the two treatment means, and for *V. americana*, we resampled the *F* statistic and then the pairwise difference in the three means.

For *P. anserina*, we found no significant differences between the two treatments in the total number of ramets per plot (mean difference = 3.07;  $n_{\text{unfert}} = 9$ ,  $n_{\text{fert}} = 8$ ,  $p = 0.28$ ; Figure 1A), but a borderline difference in the total number of flowers per plot (difference = 4.04,  $p = 0.08$ ; Figure 1B). None of the *P. anserina* ramets set seed. For *V. americana*, we found significantly more ramets in the NPK treatment compared to the control ( $F_{2,25} = 3.00$ ,  $p = 0.025$ ), and the PK treatment was intermediate (Figure 1C). Only three of all the *V. americana* plots produced flowers (Figure 1D), and only one plot produced seed. Although we found some differences, we were unable to increase seed output for either species, despite two years of spring fertilization.

Eriksson (1987) found pollen, rather than nutrients, limited seed set in a northern Sweden population of *P. anserina*, but that population had higher plant and flowering densities than those tested here. Relatively low *P. anserina* flower and plant density in our plots may have reduced pollinator attraction and the amount of compatible pollen sources (Ashman et al. 2004, Waites and Ågren 2004), potentially leading to poor seed set in our study.



**Figure 1.** Box plots of the total numbers of: A) ramets per plot; B) flowers per plot for *Potentilla anserina*; C) ramets per plot; and D) flowers per plot for *Vicia americana*. Treatments are control with no fertilization; PK with phosphorus and potassium fertilizers at a rate of 4 g m<sup>-2</sup>; and NPK with nitrogen, phosphorus and potassium fertilizers at the same rate. Lowercase letters indicate significantly different means based on pairwise permutation test on mean differences ( $p \leq 0.05$ ; 10,000 random shuffles).

For *V. americana*, which had significantly more ramets in NPK fertilized than control plots, the newly-introduced nutrients appear to have been allocated to vegetative growth before sexual reproduction; a common trade-off allocation strategy among perennial plants (Wilson and Thompson 1989, Obeso 2002). The single *V. americana* plot that we found producing seed was growing among N-fixing *Alnus incana* ssp. *rugosa* (speckled alder) and was observably larger than other plants within our plots. Outside of our experiment, we observed that other *V. americana* plants growing with *Alnus* produced seed. Besides N-fixation, *Alnus* shrubs may allow vetch to climb and reach a larger size and offer root protection during annual ice break up.

The short growing season and the relatively short time-frame of our study (two years) may have limited the impact of fertilization. Furthermore, the alkaline soil at our study site may also have adsorbed added nutrients, especially phosphorus (Weintraub 2011), limiting nutrient availability. However, these climatic or soil factors are difficult or impossible to manipulate. We also may not have fertilized sufficiently. Other fertilization studies reported mixed results, sometimes with increased vegetative biomass instead of sexual reproduction, more competition from surrounding plants, or even a shift to more competitive species (Daws et al. 2013, Petraglia et al. 2013). In northern climates, adding nutrients, even over the long term, may not shift a species reproductive behaviour to increase seed

yield, perhaps due to the climate restrictions or the specific reproductive strategy of that species (Grainger and Turkington 2013). These responses make it difficult to predict whether increasing the length of our study or increasing fertilizer rates would have eventually increased our seed yield for these species.

For restoration projects requiring local wild seed sources from plants with low seed outputs, using fertilizers to increase seed yield in a natural population may not be effective. We know both of these species produce seeds in other subarctic environments. This suggests that cultivating local plants under optimal conditions to produce seed is a better strategy to increase seed yield in a reasonable time frame and maintain local genetic provenance.

## Acknowledgements

This study was funded through a research contract with De Beers Canada and salary support from the Natural Sciences and Engineering Research Council of Canada. We gratefully acknowledge field assistance from A. Hanson, B. Polowich, J. Lavigne, and A. Borynec. We thank the personnel at the De Beers Canada Victor Mine.

## References

- Ashman, T.L., T. Knight, J.A. Steets, P. Amarasekare, M. Burd, D.R. Campbell, et al. 2004. Pollen limitation of plant reproduction: ecological and evolutionary causes and consequences. *Ecology* 85:2408–2421.
- Burd, M. 1994. Bateman's principle and plant reproduction: The role of pollen limitation in fruit seed set. *The Botanical Review* 60:83–139.
- Daws, M.I., R.J. Standish, J.M. Koch and T.K. Morald. 2013. Nitrogen and phosphorus fertilizer regime affect jarrah forest restoration after bauxite mining in Western Australia. *Applied Vegetation Science* 16:610–618.
- Eriksson, O. 1987. Regulation of seed-set and gender variation in the hermaphroditic plant *Potentilla anserina*. *Oikos* 49:165–171.
- Garrah, K. 2013. Upland ecosystems in the Hudson Bay Lowlands provide reference conditions for the reclamation of mine waste stockpiles. MS thesis, Laurentian University.
- Grainger, T.N. and R. Turkington. 2013. Long-term nutrient enrichment differentially affects investment in sexual reproduction in four boreal forest understory species. *Plant Ecology* 214: 1017–1026.
- Gunn, C.R. and J. Kluve. 1976. Androecium and pistil characters for tribe Viciae (Fabaceae). *Taxon* 25:563–575.
- Miyaniishi, K., O. Eriksson and R.W. Wein. 1991. The biology of Canadian weeds. 98. *Potentilla anserina* L. *Canadian Journal of Plant Science* 71:791–801.
- Obeso, J.R. 2002. The costs of reproduction in plants. *New Phytologist* 155:321–348.
- Petraglia, A., M. Carbognani and M. Tomaselli. 2013. Effects of nutrient amendments on modular growth, flowering effort and reproduction of snowbed plants. *Plant Ecology & Diversity* 6:475–486.
- Shaver, A.G. and F.S. Chapin. 1995. Long-term responses to factorial, NPK fertilizer treatment by Alaskan wet and moist tundra sedge species. *Ecography* 18:259–275.


- Stephenson, A. 1981. Flower and fruit abortion: Proximate causes and ultimate functions. *Annual Review of Ecology and Systematics* 12:253–279.
- Waites, A.R. and J. Ågren. 2004. Pollinator visitation, stigmatic pollen loads and among-population variation in seed set in *Lythrum salicaria*. *Journal of Ecology* 92:512–526.
- Weintraub, M. 2011. Chapter 12. Biological phosphorus cycling in arctic and alpine soils. Pages 215–244 in E.K. Bunemann, A. Oberson, and E. Frossard, (eds), *Phosphorus in action: Biological processes in soil phosphorus cycling*. Berlin, Germany: Springer-Verlag.
- Wilson, A. and K. Thompson. 1989. A comparative study of reproductive allocation in 40 British grasses. *Functional Ecology* 3:297–302.



## ***Ammophila arenaria* as a Nurse Plant: Implications for Management of an Invasive Species**

Julea A. Shaw (Department of Plant Sciences, University of California, Davis, CA, 95616 USA, [jashaw@ucdavis.edu](mailto:jashaw@ucdavis.edu)).

*Ammophila arenaria* (European beachgrass) was initially introduced to California from the coasts of Europe and North Africa to stabilize dunes and has since become a dominant invasive species on dune habitats along the west coast of the United States (Wiedemann and Pickart 1996). *Ammophila arenaria* primarily spreads by a rhizome network that is stimulated by active sand burial, allowing the species to rapidly stabilize shifting sand dunes (Buell et al. 1995). The rapid spread of dense stands of *A. arenaria* has caused a reduction in native plant richness and abundance (Wiedemann and Pickart 1996). However, at lower densities, *A. arenaria* may not have a negative impact on native plant species diversity and could even play a facilitative role (J. Solins, University of California, Davis, unpub. data). Tall vegetative structures such as shrubs often act as nurse species by providing a wind break, shade and soil stabilization for smaller plants and seedlings in dune systems (Shumway 2000, Rudgers and Maron 2003, Castanho et al. 2015). Due to a more favorable microclimate, herbaceous vegetation under shrubs and bunchgrasses are often larger, and have a higher reproductive output, compared to individuals in open areas (Shumway 2000). Given that *A. arenaria* is a tall species relative to most dune plants that stabilize soil, it has potential to act as a nurse plant.

 Supplementary materials are freely available online at: <http://uwpress.wisc.edu/journals/journals/er-supplementary.html>

*Ecological Restoration* Vol. 36, No. 2, 2018

ISSN 1522-4740 E-ISSN 1543-4079

©2017 by the Board of Regents of the University of Wisconsin System.

Although considering the positive impacts of invasive species can make management decisions more complicated, it is necessary to fully understand potential consequences of invasive species removal. If invasive species have positive impacts on native diversity, then additional management may be required to mitigate negative impacts of invasive species removal. For example, if native shrubs or bunchgrasses provide favorable microclimates similar or superior to those created by *A. arenaria* (i.e., Rudgers and Maron 2003), then active planting of these native nurse species may be a beneficial practice. This study examines: 1) whether *A. arenaria* is facilitating a more diverse native community than areas in the absence of a tall vegetative structure; 2) whether understory communities differ under *A. arenaria* and *Baccharis pilularis* (coyote brush), a widespread native shrub; and 3) whether the presence of *A. arenaria* and *B. pilularis* have a similar effect on native plant diversity.

I conducted this study at the UC Davis Bodega Marine Reserve in Bodega Bay, California, US, on sand dunes with low (< 30%) *A. arenaria* cover. *Ammophila arenaria* was introduced to the property in the 1920s–1950s to stabilize naturally shifting sand dunes and has since spread through most of surrounding areas. I visually estimated the percent cover of each species in the 0.5 m<sup>2</sup> area where vegetation grew most densely under 12 *A. arenaria* and 12 *B. pilularis* individuals (hereafter, focal species), and within twelve 0.5 m<sup>2</sup> control plots where no shrubs or bunchgrasses were present. I randomly selected all sampling sites among focal species and open areas that were not within 0.5 m of another shrub or bunchgrass. To provide insight into characteristics of nurse species that may affect their understory communities, I recorded the focal species' height, width at the widest diameter, percent canopy cover over the sampled understory vegetation and the cardinal direction of the sample area relative to the base of the focal species.

I calculated Shannon diversity in each plot using the species percent cover estimates. I then used a linear model and ANOVA to determine if there were differences in diversity among treatment groups, and performed mean comparisons using a Tukey test ( $p \leq 0.05$ ). To examine whether communities differ under different nurse species, I used Non-metric Multidimensional Scaling (NMDS) with the Bray-Curtis dissimilarity index to visualize differences among plant communities, and PERMANOVA to test for significant differences in the community composition among groups. I conducted all analyses using R (v.3.2.3, R Foundation, Vienna Austria), and used the R package “vegan” to calculate Shannon diversity and to perform NMDS and the PERMANOVA.

Comparing focal species characteristics indicated that, on average, *A. arenaria* was taller (height: 0.56 m  $\pm$  4.51 SE), narrower (width: 0.82 m  $\pm$  11.2 SE), and had a lower canopy cover (canopy cover: 7.42 %  $\pm$  3.23 SE) than did *B. pilularis* (height: 0.33 m  $\pm$  4.52 SE; width: 1.23 m