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ESTIMATING INVADING CALLERY PEAR (*PYRUS CALLERYANA*) AGE AND FLOWERING PROBABILITY IN AN INDIANA MANAGED PRAIRIE

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ABSTRACT. Callery pear (*Pyrus calleryana* Decne.) is an invasive species in North America originating from Asia. As an ornamental tree, Callery pear has been widely planted throughout much of the United States and has subsequently spread into natural areas. Callery pear individuals that had naturally colonized a managed prairie in Indiana were collected. Tree height and root collar diameter were measured and the presence of flower buds was identified. After harvesting the trees, age was measured as ring counts. Height, root collar diameter, and age were all significantly greater for flowering individuals compared to non-flowering trees. Root collar diameter was the only independent variable that resulted in a significant linear model for predicting tree age. Additionally, root collar diameter effectively predicted the likelihood of flowering in Callery pear, with a tree root collar diameter of 45.6 mm predicting a 50% chance of flowering. Age was an ineffective independent variable in predicting flowering potential in Callery pear. Root collar diameter can provide a rapid assessment of invasion age, as well as predicting flowering potential outside of the growing season. Management focus can be on larger individuals.

Keywords: Bradford pear, Callery pear, invasive species, prairie, *Pyrus calleryana*

INTRODUCTION

Callery pear (*Pyrus calleryana* Decne. [Rosaceae]) was introduced to North America from Asia in the late 1910s due to apparent resistance to fire blight (Reimer 1925; Culley & Hardiman 2007). In 1952, Callery pear began to be tested as an ornamental tree, became commercially available in 1962, and by the 1970s became a commonly planted tree in sub-division developments (Whitehouse et al. 1963; Creech 1973). This popularity in ornamental plantings has led to widespread distribution of Callery pear throughout much of the United States (Vincent 2005; Culley & Hardiman 2007).

While cultivars of Callery pear (specifically 'Bradford') were promoted as being sterile, this sterility was likely only self-incompatibility and led to reproductively successful individuals via cross-pollination with intraspecific and interspecific hybridization (Westwood & Bjornstad 1971; Vincent 2005; Culley & Hardiman 2009). Fruits are readily consumed by birds, which are effective seed dispersal agents (Reichard et al. 2001; Culley & Hardiman 2007). Due to reproductive abilities, Callery pear has consequently spread out of cultivation into disturbed habitats, which include old-fields, fence rows, and other early- to mid-successional areas (Vincent 2005).

Because of limited shading and potential for repeat disturbances, natural and constructed prairie habitats are vulnerable to invasion by Callery pear (Taylor et al. 1996; Freeman et al. 2003). Reduced light availability in closed canopy forests likely limits the ability of Callery pear to colonize those ecosystems (Flory & Clay 2006). In locations colonized by Callery pear, cutting and herbicide applications are typically the only management tool that is effective (Swearingen et al. 2010). Controlled burns in prairies as a management technique does not appear to reduce Callery pear density and results in more shoots per individual root stock due to epicormic sprout production (Warrix 2016).

Intuitively, control of invasive species is more effective if applied before reproductive events (i.e., before further dispersal can occur). Determining variables that allow for prediction of the likelihood of Callery pear flowering could help resource managers in their efforts to control this invasive species. The objectives of this study were to 1) predict Callery pear individual ages using easily measured metrics (height and root collar diameter); and 2) evaluate tree size and age as

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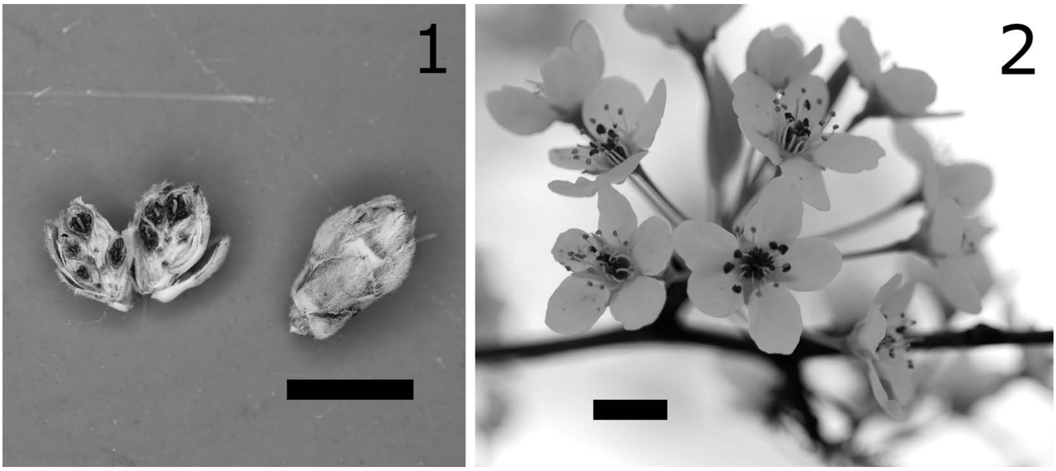

Figures 1 & 2.—Callery pear (*Pyrus calleryana*). 1. Flower buds. 2. Flowers. Black bars represent 1 cm.

variables in predicting Callery pear individual flowering.

METHODS

Callery pear individuals were collected from Arrowhead Prairie, Allen County, Indiana (41°00′13″ N, -85°19′7″ W). The property was acquired by Little River Wetlands Project in 2000 and has undergone conversion from row crop agriculture to native prairie plant species. This conversion to native species was conducted with several plantings in 2005, 2006, and 2009 (LRWP no date a, b). We harvested trees from the western edge of the property outside of an area that is actively managed with fire (Betsy Yankowiak, Pers. Comm.). In March 2016, trees were randomly selected as they were encountered during a stochastic survey ($N = 32$), assessed for presence of flower buds (Figs. 1 & 2), measured for height to the terminal bud (cm) and root collar diameter (stem diameter at the soil surface, mm), and then harvested by cutting at the soil surface. Stumps were treated with 50% glyphosate immediately after cutting as a courtesy to Little River Wetlands Project. The base 10 cm of each tree were collected, air dried, sanded with 500 grit sandpaper, dyed with phloroglucinol (20 % HCl), and rings were counted.

Height, root collar diameter, and age were compared between flowering and non-flowering individuals using individual Student's t-tests. Pearson's correlation coefficient was calculated relating height and root collar diameter for all trees pooled. The assumption of normally distributed data was tested using Shapiro-Wilk normality tests.

To predict Callery pear individual ages based on tree height and root collar diameter, tree data were randomly separated into two equal, non-overlapping groups: model development and model testing. To select individuals randomly, a stratified selection technique was used to ensure that both flowering and non-flowering trees were equally represented in the two model groups. Model development trees (i.e., tree data to develop prediction models) were used to calculate linear regression models predicting age (dependent variable) based on height and root collar diameter (independent variables). Akaike information criterion (AIC) was used to rank models (Akaike 1973). Ranking models based on AIC values takes into account model goodness of fit and complexity (i.e., models with better goodness of fit and fewer independent variables rank higher than models with poorer fit and more variables). Model testing trees were then used to test selected model effectiveness in predicting age by paired t-test comparing observed and predicted ages. Using logistic regression, we fit a sigmoidal model predicting probability of flowering using the independent variables from the best age predicting models, as well as age. All statistical tests were conducted in R (R Core Team 2015).

RESULTS

Of the 32 trees collected, eight had flower buds (Fig. 1). Height, root collar diameter, and age all met the assumption of normality. Height and root collar diameter were greater in flowering individ-

Table 1.—Comparison of mean height, root collar diameter, and age (with standard error) between Callery pear (*Pyrus calleryana*) individuals with and without flower buds.

Status	Count	Height (cm)	Root collar (mm)	Age (years)
Flowering	8	266.4 (7.9)	59.6 (2.0)	6.12 (0.35)
Non-flowering	24	198.1 (10.1)	35.1 (2.0)	5.13 (0.19)

uals compared to non-flowering individuals (height: $t_{(1)} = 5.31$, df = 30, $P < 0.001$; root collar: $t_{(1)} = 6.73$, df = 30, $P < 0.001$; Table 1). Flowering trees were significantly older ($t_{(1),29} = -2.58$, $P = 0.008$); however, the difference between these two groups was only one year (Table 1). Additionally, height and root collar diameter were significantly correlated (Fig. 3).

Simple linear models relating Callery pear age to height alone, root collar diameter alone, height and root collar diameter without interaction, and height and root collar diameter with interaction were tested. However, the model with root collar diameter was the only one to result in a significant linear regression (age = 3.469 + 0.049*root collar diameter, $F_{1,14} = 5.03$, $P = 0.042$, $R^2 = 0.26$). Since none of the other models were significant, comparison of AIC values was moot. From this single linear equation, age was calculated for the model testing group of trees (i.e., predicted age). Paired mean observed and predicted ages were not significantly different for the model testing group of trees using the root collar diameter model (t = -0.94, df = 14, $P = 0.366$). Additionally, the observed ages and predicted age residuals were not significantly correlated (r = 0.45, $P = 0.094$).

Using logistic regression, we calculated sigmoidal curves using our model development group to predict the probability of flowering and tested those models with our model test group. Using root collar diameter as the independent variable to predict flowering probability resulted in a significant logistic regression (F = 17.88, df = 2,13, $P < 0.001$, $R^2 = 0.86$; Eq. 1).

$$p(\mathit{flowering}) = \frac{0.800}{1 + e^{-\frac{(root\ collar\ diameter - 45.508)}{0.172}}} \qquad \text{(Equation 1)}$$

A probability of 0.5 was selected as an arbitrary threshold to predict if a tree would flower. Using that threshold, the root collar model correctly predicted flowering for 93.8% of trees in the model test group. The model incorrectly predicted flowering for a tree that did not flower, which coincidently happened to be an individual with an asymmetrical stem due to damage on one side. The logistic regression model that included root collar diameter predicted greater than 0.5 probability of flowering for individual trees with root collar diameters greater than 45.6 mm. Using observed age as the independent variable to predict flowering probability resulted in a significant logistic regression model (F = 4.88, df = 2,13, $P = 0.026$, $R^2 = 0.65$; Eq. 2).

$$p(\mathit{flowering}) = \frac{0.571}{1 + e^{-\frac{(age - 5.326)}{0.027}}} \qquad \text{(Equation 2)}$$

Using the same 0.5 probability threshold, the age logistic regression model correctly predicted flowering 68.8% of the trees in the model test group. Incorrect flowering predictions occurred in both flowering and non-flowering trees.

DISCUSSION

Callery pear has effectively spread out of cultivation and has established self-sustaining populations in natural areas (Vincent 2005). Birds

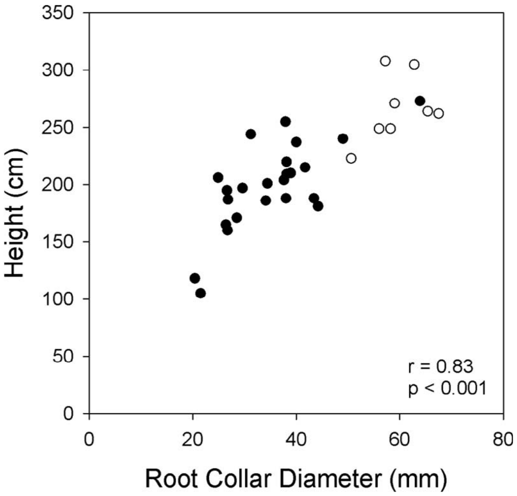

Figure 3.—Scatter plot of Callery pear (*Pyrus calleryana*) root collar diameter versus height with Pearson's correlation. Closed circles represent individuals without flower buds; open circles represent individuals with flower buds.

regularly feed on fruits when available and act as effective seed vectors (Culley & Hardiman 2007). Curtailing this spread requires use of labor intensive control methods, such as cutting and herbicide application (Swearington et al. 2010).

Even though height and root collar diameter were correlated, height was not an effective predictor of age. The correlation between these two growth variables was expected (e.g., Hara et al. 1991). Our root collar diameter model successfully predicted ages when compared to the observed ages. Differences in paired t-tests (and rejecting the null hypothesis that the paired observed and predicted values were equal) would have suggested poor age prediction by the model. However, no age difference was found with a paired t-test between our predicted and observed ages in the model testing group. Significant correlation between observed ages and predicted age residuals would have suggested poor age prediction of either young or old trees (e.g., positive correlation would have resulted from greater predicted residuals as trees increase in age, which would suggest the model was effective only for young trees). The correlation null hypothesis (i.e., rho is equal to zero) was not rejected. Since neither of these two tests rejected the null hypotheses, we interpret the model as being effective.

Using our sigmoidal curve equation, trees with a root collar diameter of 45.6 mm had a flowering probability of 0.5, which aligned with an age prediction of nearly six years old. In our complete data set, ten trees were greater than 45.6 mm, two of which did not flower. Those two non-flowering trees are identifiable in the height and root collar diameter correlation clustering with flowering trees. Conversely, 12 trees in our complete data set were six years old or older, half of those were non-flowering trees. This supports our interpretation that age is a poor predictor of flowering potential. Culley & Hardiman (2007) stated that Callery pear trees can start flowering as early as three years old. None of our trees that young were flowering nor were they large enough to flower, based on the results presented here. The potential for a Callery pear individual to flower at three years old likely relies on optimal growing conditions. Due to high root:shoot ratios of dominant prairie plants, belowground competition in prairies is high and subsequently reduces aboveground biomass of trees (Wilson 1993). Our results suggest that age is not a strong predictor of flowering potential in Callery pear, especially in sub-optimal growing conditions. By using root collar diameter, we were successful in predicting the flowering potential of Callery pear invading a managed prairie.

Predicting flowering potential for Callery pear may be important in actively managing this species. Ages we observed in this prairie suggest that there was a time-lag between the cessation of row crop agriculture following acquisition by Little River Wetlands Project and when Callery pear began colonizing the property (oldest trees were 8 years old). Competition for light, space, and other resources, may make some natural areas sub-optimal for Callery pear growth and may then extend the maturation time leading to flowering. This extended time window may provide more opportunity for successful control of Callery pear in natural areas, which is promising since effective management technique is a time consuming and labor intensive method. Hence, managers should focus control efforts on the largest Callery pear individuals, since smaller individuals are unlikely to flower and produce seed for further colonization in the immediate future. Further research is needed into the effect of prescribed fires on the association between tree size and flowering. Sprouts post-fire will be associated with large root collars and large root systems. This may alter the association between tree size and flowering.

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LITERATURE CITED

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pp 267–281. *In* Second International Symposium on Information Theory. (B.N. Petrov & B.F. Csaki, Eds.). Academiai Kiado, Budapest, Hungary.

Creech, J.L. 1973. Ornamental plant introduction – building on the past. Arnoldia 33:13–25.

Culley, T.M. & N.A. Hardiman. 2007. The beginning of a new invasive plant: a history of the ornamental Callery pear in the United States. Bioscience 57:956–964.

Culley, T.M. & N. A. Hardiman. 2009. The role of intraspecific hybridization in the evolution of invasiveness: a case study of the ornamental pear tree *Pyrus calleryana*. Biological Invasions 11:1107–1119.

Flory, S.L. & K. Clay. 2006. Invasive shrub distribution varies with distance to roads and stand age in eastern deciduous forests in Indiana, USA. Plant Ecology 184:131–141.

Freeman, C.C., C.A. Morse & R.L. McGregor. 2003. New vascular plant records for the grassland biome of central North America. Sida 20:1289–1297.

Hara, T., M. Kimura & K. Kikuzawa. 1991. Growth patterns of tree height and stem diameter in populations of *Abies veitchii*, *A. mariesii*, and *Betula ermanii*. Journal of Ecology 79:1085–1098.

LRWP. No date a. Arrowhead Prairie Plantings. Little River Wetlands Project. At: http://www.lrwp.org/api/f0e13de0fdc63531b9b75ecf1b24ae02/Arrowhead_Prairie_Plantings.pdf (Accessed 2 October 2017).

LRWP. No date b. Arrowhead Prairie Addition's Plant List. Little River Wetlands Project. At: http://www.lrwp.org/api/f0e13de0fdc63531b9b75ecf1b24ae02/Arrowhead_Prairie_Additions_Plantings.pdf (Accessed 2 October 2017).

R Core Team. 2015. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Version 3.2.3. At: http://www.R-project.org (Accessed 30 June 2017).

Reichard, S.H., L. Chalker-Scott & S. Buchanan. 2001. Interactions among non-native plants and birds. Pp 179–223. *In* Avian Ecology and Conservation in an Urbanizing World. (J.M. Marzluff, R. Bowman & R. Donnelly, Eds.). Kluwer Academic Publishers, Boston, Massachusetts.

Reimer, F.C. 1925. Blight Resistance in Pears and Characteristics of Pear Species and Stocks. Oregon Agricultural College Experiment Station, Station Bulletin 214, Corvallis, Oregon. 99 pp.

Swearington, J., B. Slattery, K. Reshetiloff & S. Zwicker. 2010. Plant Invaders of Mid-Atlantic Natural Areas. National Park Service and U.S. Fish and Wildlife Service, Washington, DC. 168 pp.

Taylor, C.E.S., L.K. Magrath, P. Folley, P. Buck & S. Carpenter. 1996. Oklahoma vascular plants: additions and distributional comments. Proceedings of the Oklahoma Academy of Science 76:31–34.

Vincent, M.A. 2005. On the spread and current distribution of *Pyrus calleryana* in the United States. Castanea 70:20–31.

Warrix, A.R. 2016. Management of Remnant Prairie Ecosystems: Soil Transfer, Fire, and Exotic Species Invasion. MS thesis, Purdue University, Fort Wayne, Indiana. 62 pp.

Westwood, M.N. & H.O. Bjornstad. 1971. Some fruit characteristics of interspecific hybrids and extent of self-sterility in *Pyrus*. Bulletin of the Torrey Botanical Club 98:22–24.

Whitehouse, W.E., J.L. Creech & G.A. Seaton. 1963. Bradford ornamental pear – a promising shade tree. American Nurseryman 117:56–60.

Wilson, S.D. 1993. Belowground competition in forest and prairie. Oikos 68:146–150.

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