Environmental Correlates to Population Structure and Health of the Rare Piratebush (Buckleya distichophylla) within Poor Mountain Natural Area Preserve, Virginia

Authors: Huish, Ryan, and Klopf, Ryan

Source: Natural Areas Journal, 38(2) : 148-153

Published By: Natural Areas Association

URL: https://doi.org/10.3375/043.038.0205

RESEARCH ARTICLE

•

Environmental Correlates to Population Structure and Health of the Rare Piratebush (*Buckleya distichophylla*) within Poor Mountain Natural Area Preserve, Virginia

Ryan Huish[1,3]

[1] The University of Virginia's College
at Wise
Department of Natural Sciences
1 College Avenue
Wise, VA 24293

Ryan Klopf[2]

[2] Virginia Department of Conservation
and Recreation
Division of Natural Heritage
5162 Valleypointe Parkway
Roanoke, VA 24019

•

Natural Areas Journal 38:148–153

ABSTRACT: Piratebush (*Buckleya distichophylla*, Santalaceae) is a dioecious, hemi-parasitic shrub endemic to the Blue Ridge Ecoregion of the Appalachian Mountains. The Poor Mountain Natural Area Preserve (PMNAP) in southwestern Virginia protects the densest known population of this rare plant. Permanent transects were set within this natural area to measure population density, size-class structure and health indicators, and to analyze their relationship to ecological parameters. Within PMNAP, there were 9 ± 2 piratebush per 100 m^2 of forest floor with a mean size of 4 ± 1 stems of 1.9 ± 0.6 cm diameter at ground height. Individual shrubs grew across a broad range of aspects, slopes (2–50%), and canopy cover (0–100%), exhibiting minimal crown death and a wide range of foliar color value. Weighted size class structure distribution was positively skewed, with low indication of recent seedling recruitment. Observed adventitious vegetative regeneration may mask the frequency of genetically distinct individuals, and indicate less genetic diversity within this population. Weighted size class was positively correlated to forest canopy cover ($P < 0.001$) and southerly aspect ($P = 0.071$). Foliar color value was positively correlated with canopy openness ($P < 0.001$) but neither weighted size class nor plant vigor. This study indicates that successful sexual reproduction within this piratebush population may be rare, and establishes a detailed baseline assessment of the largest extant piratebush population, enabling future study of factors relevant to the long-term viability of this species.

Index terms: Buckleya distichophylla, piratebush, plant ecology, rare plant, shrub size class, size-class structure

INTRODUCTION

Piratebush (*Buckleya distichophylla* [Nutt.] Torr.) is a rare, hemi-parasitic, dioecious shrub in the sandalwood family (Santalaceae), endemic to the Southern Appalachian Mountains of Virginia, North Carolina, and Tennessee (Leahy et al. 2006). Populations of piratebush occur within a variety of pine and acidic mixed-oak forests (450–1100 m) within the Blue Ridge and Ridge and Valley physiographic provinces (Mowbray 1985; NatureServe 2017). With only about 25 isolated populations, piratebush is ranked as "imperiled" in all three states (Plant Industry Division 2010; Townsend 2012; Crabtree 2014).

Piratebush has multiple main stems, up to 5 m in length, with simple, opposite or subopposite, lanceolate leaves. Small greenish flowers are borne at the apices of branches in clusters for males and singly for females. Females produce a single seeded, yellowish green, ellipsoid drupe of 1–2 cm (Musselman 1982; Weakly et al. 2012). Previous research is limited and raises many questions on the ecology and habitat preferences of this rare and curiously scattered species. Specifically, the forest community (i.e., pine–oak/heath woodland) within which piratebush may be found appears to be far more common than piratebush itself. Conservation and study of rare plants is important for maintaining biodiversity. Rare plants may be more sensitive to global change and stochastic events and, therefore, inherently more complex to sustainably manage than common species (Schemske et al. 1994; Matthies et al 2004). Habitat preservation is fundamental for conservation (Noss 1983) but maintaining genetic variation cannot be overlooked, with population size having a large effect on breeding capacity and genetics (Barrett and Kohn 1991).

The densest known population of piratebush grows within the Poor Mountain Natural Area Preserve (PMNAP) in southwestern Virginia (Leahy et al. 2006). Piratebush was first recorded on Poor Mountain in 1980 (DCR-DNH EO Data Viewer Database, accessed 29 August 2014) and land protection for the plant began in 1989. Research on PMNAP by Leahy et al. (2006) investigated the composition and structure of woody plant species associated with piratebush and characterized the forest types where piratebush is found on Poor Mountain as xeric and dominated by pine–oak/heath communities. Within this particular forest type in PMNAP, we collected data on the population structure and health of piratebush using permanent transects. Data analyses sought to determine possible correlations between various ecological parameters (e.g., forest community and environmental variables) and piratebush size, density, and health indicators. These data and analyses improve our understanding of piratebush ecology and habitat preferences, create a baseline for long-term monitoring of population dynamics, and help inform

---

[3] Corresponding author:
rdh5b@uvawise.edu; (276) 328-0262

successful management of this rare and unique species.

METHODS

Study Area

This study was conducted at Poor Mountain Natural Area Preserve (PMNAP) in Roanoke County, Virginia (37°13′N, 80°05′W). This 375-ha preserve is managed by the Virginia Division of Natural Heritage for the protection and restoration of rare elements of biodiversity found within its Central Appalachian pine–oak/heath woodland. Present ecological intervention management (Hobbs et al. 2011) primarily consists of chemical and mechanical control of invasive species (e.g., garlic mustard *Alliaria petiolata* [M.Bieb.] Cavara & Grande and Japanese stiltgrass *Microstegium vimineum* [Trin.] A. Camus). PMNAP lies atop steep slopes on the northeast end of Poor Mountain (455–818 m elevation) within the Blue Ridge physiographic region. Soils are excessively drained gravelling loams derived from igneous and metamorphic rocks of the Chilhowee Group in the Blue Ridge anticlinorium (Rader and Evans 1993; Leahy et al. 2006). Average annual total precipitation ~14 km east of PMNAP in Roanoke (358-m elevation) is 104 cm and mean annual temperature is 13.7 C (NOAA 2016).

Data Collection

Data were collected in late summer to early fall 2011 using belt transect sampling, following the methods of Hill et al. (2005), Peters (1994, 1996a, 1996b), and Hall and Bawa (1993). We established 11 permanent transects consisting of 2 × 5 m contiguous plots through the population and to traverse topographical and elevational gradients. The length of each transect ranged from 50 to 250 m as determined by the natural range of the population. Transects were spaced 40 m apart at intersections with the PMNAP trail, georeferenced with GPS and compass coordinates, and oriented parallel with the terrain slope.

In each plot, we made a series of measurements for each individual piratebush and its habitat. Individual piratebush measurements included perpendicular distance to transect line, distance down the transect line, length of longest stem, number of stems, and diameter at ground height (dgh) when over 1 cm in dgh. Species of indeterminate growth (e.g., woody plants) vary tremendously in size, height, and biomass. To estimate plant biomass without necessitating destructive sampling of this rare shrub, we calculated a weighted size using the individuals' stem count, length of the longest stem, and the diameter at ground height. Weighted size class (WSC) = (0.4 × max stem length) + (0.4 × dgh) + (0.2 × number of stems). Individuals were then categorized into one of five weighted size classes (index values of 0–40, 41–80, 81–120, 121–160, 160+) to determine the size-class structure of the piratebush population. The relative importance given to these three metrics was based on their assumed contribution to fitness and size. We recorded foliar color value and vigor class as health indicators for each individual piratebush. We estimated foliar color value by applying a rating scale of 1–4, with 1 representing the lightest green leaf tissue and 4 representing the darkest green. We assessed plant vigor class by estimating percent crown death using a rating scale of 1–4: 1 = dead, 100% crown death; 2 = poor, 50–90% crown death; 3 = fair, 10–50% crown death; and 4 = good, 0–10% crown death (Plummer et al. 1977).

We also recorded ecological characteristics, including percent canopy cover, slope, and the density and size of pines and oaks in each plot. Percent canopy cover was determined with a spherical densiometer. Slope was recorded for every plot along each transect using a clinometer. The size of the pine and oak was determined by measuring diameter at breast height (dbh) or height, if less than 4-cm dbh.

Data Analyses

Data were analyzed using linear correlation procedures in Sigma Plot v. 11. Specifically, we looked for correlations between our piratebush measurements (weighted size, vigor, foliar color value) and multiple biotic (pine and oak stem density, diameter, and sapling height) and abiotic (canopy cover, slope, aspect) variables. In addition, we looked for correlations between our measurements of the piratebush shrubs themselves (foliar color value and vigor, weighted size and foliar color value, weighted size and vigor) to better understand the relationship between various morphological attributes and plant quality. One-way analyses of variance (′ = 0.05) were used to test for differences between the stem densities of different tree species in the piratebush community. Mean values are reported with plus or minus one standard deviation.

RESULTS

Within PMNAP, the piratebush population we sampled was distributed across 14 ha, with 9 ± 2 piratebush per 100 m^2 of the forest floor. The average size of piratebush was 4 ± 1 stems of 1.9 ± 0.6 cm diameter at ground height. The weighted size-class distribution of the entire population (Figure 1a) shows a positive skewness, typical of age-class distribution for plant populations (Peters 1996a, 1996b). A closer examination of the smallest weighted size class (Figure 1b) reveals very few small (i.e., 0–10 WSC; possible seedlings) individuals of piratebush within the population.

Individual piratebush, while diverse in terms of foliar color, were overall deemed fairly healthy and vigorous. Average plant vigor, based on percent crown death, was estimated to be fair to good at 3.8 ± 0.2, and average foliar color value was estimated at 2.8 ± 0.6. Specifically, 80% of the piratebush were assigned a vigor class of 4 (good) and 14% were 3 (fair; Figure 2a). Foliar color value spanned a wider range: 29% had the greenest foliage, color value of 4; 28% had a color value of 3; 24% had a color value of 2; and 19% had a color value of 1 (Figure 2b). Piratebush vigor and foliar color value were uncorrelated ($P = 0.10$) and there was also no significant relationship between weighted size and foliar color ($P > 0.10$), nor weighted size and plant vigor ($P > 0.10$).

Canopy cover above the piratebush popu-

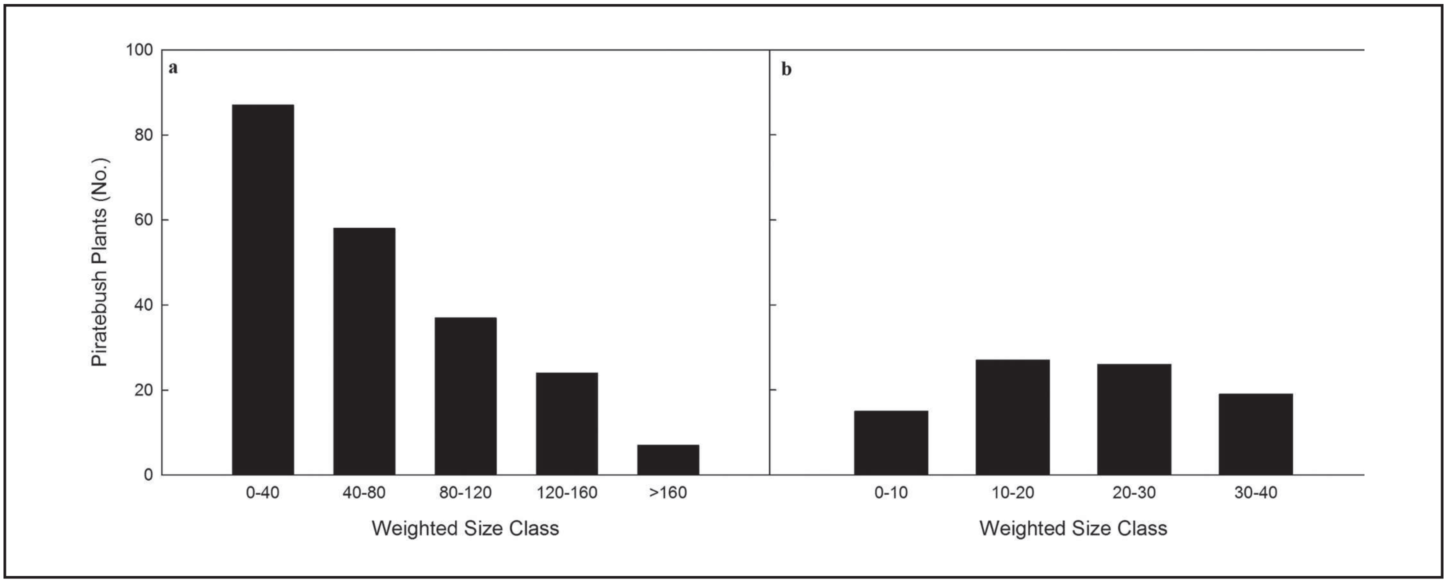

Figure 1. Weighted size class distribution of the entire piratebush population (a) and weighted size class distribution within the smallest piratebush size class (b) at Poor Mountain Natural Area Preserve (2011).

lation ranged from 0 to 100%. Plots with piratebush had significantly lower mean canopy openness (65 ± 24%) than plots without piratebush (75 ± 22%) ($P < 0.001$). Piratebush weighted size increased as canopy openness decreased ($P < 0.001$, $r = -0.242$; Figure 3). There was no correlation between plant vigor and canopy cover ($P > 0.10$), but there was a strong correlation between piratebush foliar color value and canopy openness ($P < 0.001$, $r = 0.601$) with foliar color value increasing as the canopy became more open.

Slope in plots containing piratebush ranged from 2 to 50%. Average slope for plots with piratebush (22 ± 9%) was similar to slope in plots lacking piratebush (24 ± 10%) ($P > 0.10$), and slope showed no correlation to weighted size ($P = 0.22$).

Aspect for plots with piratebush ranged from south to north, with a weak relationship between the weighted size of piratebush and aspect ($P = 0.071$, $r = -0.113$), showing increases in piratebush weighted size corresponding to less northern and more southern aspects.

The pine–oak/heath woodland community that contains piratebush had 3 ± 1 large chestnut oak (*Quercus montana* L.) stems per 100 m^2, 2 ± 1 large red oak (*Quercus rubra* L.) stems per 100 m^2, and 5 ± 4 large pines (*Pinus* spp.) stems per 100 m^2. Stem density of chestnut oak and pines were similar ($P = 0.26$), but stem density of pines was greater than stem density of red oak ($P = 0.05$). Saplings of chestnut oak, red oak, and pines were measured at

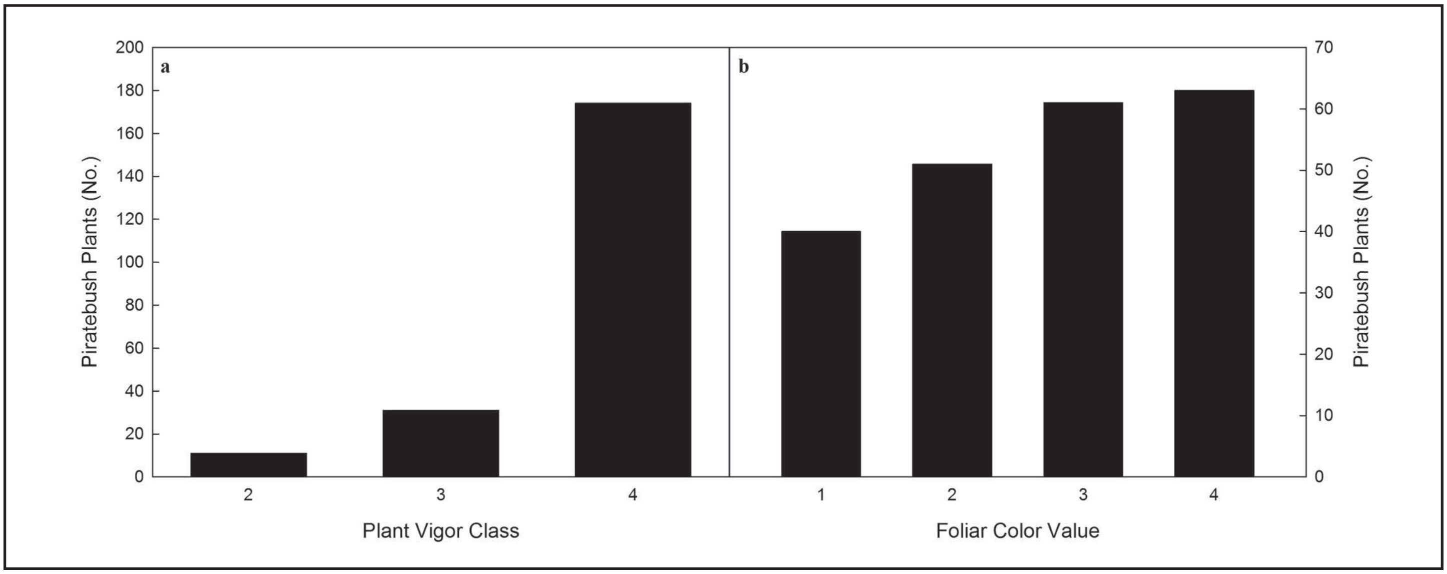

Figure 2. Distribution of individual piratebush plants by vigor class (a) and foliar color value (b) at Poor Mountain Natural Area Preserve (2011).

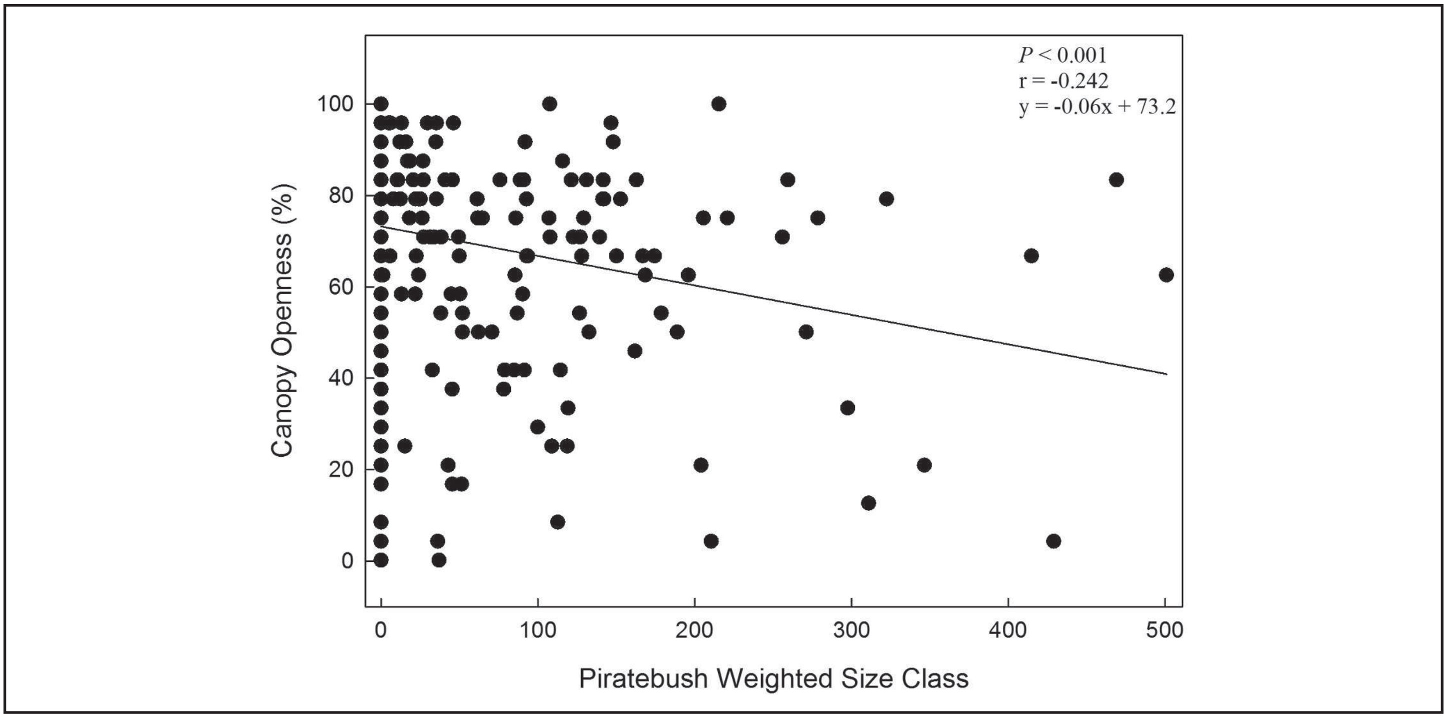

Figure 3. Piratebush weighted size correlated with forest canopy openness at Poor Mountain Natural Area Preserve (2011).

similar ($P > 0.05$) densities of 4 ± 5, 9 ± 8, and 4 ± 3 stems per 100 m^2, respectively.

There was a positive correlation between the number of red oak saplings and weighted size of piratebush ($P = 0.024$, $r = 0.141$), but there were no correlations between the height of red oak saplings and piratebush. Neither the density, nor the dbh of large red oak was correlated with piratebush weighted size ($P > 0.10$). Neither the density of large chestnut oak ($P = 0.081$) nor the density of chestnut oak saplings ($P = 0.924$) was correlated with weighted size of piratebush. Similarly, neither sapling height nor large chestnut oak dbh were correlated with piratebush weighted size ($P > 0.10$). Sapling height of the pines was positively correlated with the weighted size of piratebush ($P = 0.071$, $r = 0.383$), but sapling density was not ($P > 0.10$). Neither large pine density nor dbh was correlated with piratebush weighted size ($P > 0.10$).

DISCUSSION

The exact nature of population regeneration and recruitment for this population remains difficult to understand. The population seems substantially dense and structurally diverse, though there appears to be a cryptic pattern for seedling recruitment. Additionally, piratebush appears to resprout from bud banks on belowground structures around the base of the main stems, while older stems die back, making it difficult to determine the age of individuals based on size, as well as whether individuals were genets or ramets. Consequently, while the size-class structure distribution exhibits positive skewness, it may not necessarily show an accurate representation of age distribution in the population. More invasive techniques or genetic testing would be needed to reliably identify genets, and clarify the nature of root morphology and bud banking.

Nevertheless, using our best judgment in the field, and the tools available for this study, we measured a low amount of piratebush seedlings, which indicate ecological intervention may be necessary to increase reproduction and recruitment. Thick duff (>5 cm) can be a barrier to acorn success in oak forests (Dey and Fan 2009); while we did not quantify duff thickness in this study, qualitative observations within PMNAP indicate a thick duff layer is present. Conceivably this could help explain the low number of seedlings we measured. Other factors could also be at play with the reproductive success of piratebush, including sex ratio, floral phenology (Huish et al. 2015), and possible piratebush seed predation during non-mast years for the oak trees within the ecological community. The conjecture that piratebush may be a fire-adapted species is further supported by both the aforementioned observed adventitious growth, as well as its association with known fire-adapted plants (e.g., pine, oak, heath; Leahy et al. 2006).

While Leahy et al. (2006) found strong associations between piratebush and xeric table mountain pine habitat compared to other surrounding habitats at PMNAP, within this habitat type we did not find many correlations between piratebush and potential host tree species. This may further support the evidence of Musselman and Mann (1979) that piratebush has low parasitic specificity, though transect sampling methods may not accurately reveal host associations. The nature and specificity of parasitism for piratebush has been in question for some time (Howard

1977; Musselman and Mann 1979). The lack of correlation between foliar color value and plant vigor or weighted size is an indication that photosynthetic activity may not be a major constraint on growth, and if lighter foliar color value indicates a greater parasitic dependence, then greater parasitism is also not necessarily associated with improved growth or vigor. The wide range of foliar color values recorded in this study, and the increase of foliar color values with more open canopies, further suggest that piratebush parasitism and/or photosynthetic ability may be variable or adaptable, and dependent on environmental factors including canopy cover. Overall, the vigor and foliar color value of the piratebush population within PMNAP indicate that the individuals within this population are in good health.

CONCLUSIONS

The results presented here do not reveal historical factors of establishment and persistence of piratebush at PMNAP, but serve as a benchmark to assess how factors including ecological intervention (Hobbs et al. 2011; e.g., prescribed burning) and anthropogenic global change may affect sustainability of this rare plant in the future. The piratebush population at the PMNAP, while substantially dense and structurally diverse, shows discontinuity in very small individuals, presumably seedlings. Few observations of seedlings, coupled with the apparent adventitious, vegetative regeneration identify reproductive biology and genetics as key research areas for understanding the maintenance of viable piratebush populations. The efficacy of prescribed fire management for increasing recruitment of piratebush within this fire-adapted plant community is also an appropriate subject for further investigation. Individuals grow across a broad range of aspect, slope, and canopy cover, while exhibiting minimal percent crown death and a wide range of foliar color values. Results also indicate greater photosynthetic adaptability than previously known. Collectively, these findings indicate general good health of individuals, as well as site versatility within xeric pine–oak/heath habitat. These observations, coupled with the apparent commonality of habitat requirements throughout the mountains of western Virginia, suggest that the large, isolated population of piratebush on Poor Mountain is likely not due to high habitat or host specificity, but is rather due to factors which limit reproduction and dispersal. Thus, in addition to preservation of existing piratebush populations, future restoration actions will require a better understanding of the factors necessary for effective recruitment of piratebush.

ACKNOWLEDGMENTS

We would like to thank the Virginia Department of Conservation and Recreation for allowing us to perform this research in the Poor Mountain Natural Area Preserve. We also acknowledge Dr. Huish's students for their hard work in assisting with data collection.

Ryan D. Huish studied plant sciences at the City University of New York and the New York Botanical Garden (PhD). He is currently an Assistant Professor of Biology at the University of Virginia's College at Wise.

Ryan Klopf is the Mountain Region Steward and Supervisor for the Virginia Natural Heritage Program. He has a PhD in plant biology from Southern Illinois University Carbondale.

LITERATURE CITED

Barrett, S., and J.R. Kohn. 1991. Genetic and evolutional consequences of small population size in plants: Implications for conservation. Pp. 3–30 *in* D.A. Falk and K.E. Holsinger, eds., Genetics and Conservation of Rare Plants. Center for Plant Conservation, Oxford University Press, New York and Oxford.

Crabtree, T. 2014. Rare plant list. Tennessee Natural Heritage Program, Division of Natural Areas, Tennessee Department of Environment and Conservation, Nashville. Accessed 31 March 2014 from <http://www.state.tn.us/environment/natural-areas/docs/plant_list.pdf>.

Dey, D.C., and Z. Fan. 2009. A review of fire and oak regeneration and overstory recruitment. Pp. 2–20 *in* T.F. Hutchinson, ed., Proceedings of the 3rd Fire in Eastern Oak Forests Conference, 20–22 May 2008; Carbondale, IL. General Technical Report NRS-P-46, USDA Forest Service, Northern Research Station, Newtown Square, PA.

Hall, P., and K. Bawa. 1993. Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. Economic Botany 47:234-247.

Hill, D.A., M. Fasham, G. Tucker, M. Shewry, and P. Shaw. 2005. Handbook of Biodiversity Methods: Survey, Evaluation and Monitoring. Cambridge University Press, Cambridge, UK.

Hobbs, R.J., L.M. Hallatt, P.R. Ehrlich, and H.A. Mooney. 2011. Intervention and ecology: Applying ecological science in the twenty-first century. BioScience 61:442-450.

Howard, R.A. 1977. *Buckleya*—The oldest cultivated plant in the Arnold Arboretum. Arnoldia 37:151-155.

Huish, R.D., M. Manow, C.K. McMullin. 2015. Floral phenology and sex ratio of piratebush (Buckleya distichophylla), a rare dioecious shrub endemic to the Southern Appalachian Mountains. Castanea 80(1): 1-7.

Leahy, M.J., C.J. Hutto, and P.A. Clarke. 2006. The composition and structure of woody vegetation associated with piratebush, *Buckleya distichophylla* (Nutt.) Torr., on Poor Mountain, Virginia. Castanea 71:31-44.

Matthies, D., I. Bräuer, W. Maibom, and T. Tscharntke. 2004. Population size and the risk of local extinction: Empirical evidence from rare plants. Oikos 105:481-488.

Mowbray, T.B. 1985. Final status report on *Buckleya distichophylla*. Report submitted to the US Department of the Interior, Endangered Species Office, Asheville, NC.

Musselman, L.J. 1982. The Santalaceae of Virginia. Castanea 47:276-283.

Musselman, L.J., and F.W. Mann Jr. 1979. Notes on seed germination and parasitism of seedlings of *Buckleya distichophylla* (Santalaceae). Castanea 44:108-113.

[NOAA] National Oceanic and Atmospheric Administration. 2016. Local Climatological Data Annual Summary with Comparative Data: Roanoke, Virginia (KROA). National Centers for Environmental Information, Asheville, NC.

Natureserve. 2017. NatureServe Web Service. Arlington, VA. Accessed 29 December 2017 from <http://services.natureserve.org>.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. Bioscience 33:700-706.

Peters, C.M. 1994. Sustainable Harvest of Non-Timber Plant Resources in Tropical Moist Forest: An Ecological Primer. Biodiversity Support Program publication series (consortium of World Wildlife Fund, The Nature Conservancy, and World Resources Institute), Washington, DC.

Peters, C.M. 1996a. Beyond nomenclature and use: A review of ecological methods for ethnobotanists. Pp. 241–276 i*n* M.N. Alexiades, ed., Selected Guidelines for Ethnobotanical Research: A Field Manual. New York Botanical Garden Press, Bronx, NY.

Peters, C.M. 1996b. The ecology and management of non-timber forest resources. The World Bank Technical Paper 322:1-157.

Plant Industry Division. 2010. Protected plant species list. North Carolina Department of Agriculture and Consumer Services, North Carolina. Accessed 31 March 2014 from <http://www.ncagr.gov/plantindustry/plant/plantconserve/plist.htm>.

Plummer, A.P., S.B. Monsen, and R. Stevens. 1977. Intermountain range plant names and symbols. General Technical Report INT-38, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Rader, E.K., and N.H. Evans. 1993. Geologic map of Virginia and expanded explanation. Virginia Department of Mines, Minerals and Energy, Division of Mineral Resources, Charlottesville, VA.

Schemske, D.W., B.C. Husban, M.H. Ruckelshaus, C. Goodwillie, I.M. Parker, and J.G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. Ecology 75:584-606.

Townsend, J.F. 2012. Natural heritage resources of Virginia: Rare plants. Natural Heritage Technical Report, Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond. Accessed 31 March 2014 from <http://www.dcr.virginia.gov/natural_heritage/documents/plantlist12.pdf>.

Weakley, A.S., J.C. Ludwig, and J.F. Townsend. 2012. Flora of Virginia. Foundation of the Flora of Virginia Project Inc., Richmond. Botanical Research Institute of Texas Press, Fort Worth.