

Exploratory Survey of Salamanders in Pennsylvanian Forests with Dense Understories of *Berberis thunbergii* (Japanese Barberry), an Invasive Shrub

Ryan M. Utz^{1,*} and Melanie N. Fetsko¹

Abstract - We conducted a limited survey to analyze the potential effects of thick understory patches of *Berberis thunbergii* (Japanese Barberry), an invasive shrub, on forest-dwelling salamanders. Our observational survey of 4 riparian streams was aimed at addressing the hypothesis that Japanese Barberry would negatively affect salamander populations due to detrimental impacts on soil properties and native vegetation. We placed cover boards along the riparian zones of 2 streams that were heavily invaded and 2 that were sporadically invaded by Japanese Barberry in a western Pennsylvanian suburban deciduous forest. The following year, we surveyed each coverboard on 3 occasions to quantify amphibian abundance and diversity. We identified specimens to species whenever possible and quantified Japanese Barberry invasion intensity by estimating aboveground biomass. Results suggest salamander abundance was unaffected by the presence of Japanese Barberry. Species composition differed between invaded and uninvaded habitat, with more *Desmognathus* spp. salamanders dominating uninvaded sites, though data limitations prevented rigorous comparisons of community-scale differences. Our limited data are unable to determine if Japanese Barberry invasions are associated with indirect effects on salamander populations. However, the lack of any measurable effect on salamander abundance suggests that Japanese Barberry does not induce a strong direct effect on these species.

Introduction

Nonnative plant invasions represent a major concern for amphibian conservation, as they may substantially alter ecosystems via changes to habitat or prey availability. Known ecological impacts induced by invasive plants include allelopathy, competition with native plants that might be critically important to fauna, and changes to abiotic ecological attributes such as temperature (Weidenhamer and Callaway 2010, Vilà et al. 2011). Many such effects may directly or indirectly affect amphibians. For example, invasive earthworms, which may be significantly associated with plant invasions (Nuzzo et al. 2009), can lower salamander abundance and possibly the amount of prey by decreasing leaf litter (Maerz et al. 2009; Ziemba et al. 2015, 2016). Phytochemicals released by invasive plants can directly reduce larval stage survivorship by interfering with respiratory physiology (Adams and Saenz 2012, Earl et al. 2012, Watling et al. 2011a). Yet in rare instances, invasive plants may benefit some amphibian populations by providing habitat or cover (Bucciarelli et al. 2014). Therefore, the effects of an invasive plant on amphibians may vary by species and setting.

¹Falk School of Sustainability, Chatham University, 6035 Ridge Road, Gibsonia, PA, 15044.

*Corresponding author - rutz@chatham.edu.

Berberis thunbergii DC. (Japanese Barberry) is an invasive species of importance in northeastern North America because of the many ecological consequences that ensue on forest floors following invasion. For example, the abundance and diversity of native terrestrial snails in Pennsylvania forests invaded with Japanese Barberry may be higher relative to control sites (Utz et al. 2018), potentially due to the ability of the plant to create cooler and more humid microhabitat conditions. Biotic and abiotic changes associated with Japanese Barberry invasions could impact forest-dwelling amphibian communities in potentially both positive and negative ways. Recalcitrant layers of Japanese Barberry can reduce the amount of solar radiation that reaches the surface and lower mean temperatures by 1–2 °C (Link et al. 2019), potentially enhancing habitat suitability for amphibians by creating environments that are more humid. Japanese Barberry invasions may elevate population densities of ticks (*Ixodes scapularis* Say [Blacklegged Tick]; Williams and Ward 2010) and large-bodied arthropod decomposers (Clark and Seewagen 2019), both of which serve as prey for amphibians. Changes to leaf-litter attributes may also accompany Japanese Barberry invasions, as the nitrogen-rich leaf litter of this species tends to promote decomposition and elevate soil pH. However, Maerz et al. (2009) found no statistically significant direct effect of Japanese Barberry on salamander abundance and an indirect negative effect when co-invading earthworms reduced leaf-litter volume.

Given that Japanese Barberry is rapidly expanding in northeastern North American forests and potentially impacting forest understories where it spreads, we conducted an exploratory survey to determine the possible effects of its invasion on salamanders. We hypothesized that Japanese Barberry would lead to lower salamander counts and depressed biodiversity because of the reduced recruitment of native trees observed in prior studies within our study ecosystem (Link et al. 2018, 2019). We used coverboard surveys to quantify salamander abundance and species composition adjacent to 4 headwater stream riparian zones that were either heavily invaded by Japanese Barberry or with low cover of the invasive plant but otherwise possessed similar physicochemical and ecological characteristics due to their close proximity (all sites were within a 0.75-km radius) and shared land-use history.

Field Study Site

The 4 streams used in this study are on Chatham University's Eden Hall Campus, Allegheny County, in southwestern Pennsylvania. This 157-ha reserve is within the suburban northern extent of the Pittsburgh, PA, metropolitan region (40.6637477°N, 79.9580199°W). Most (>80%) of the campus is comprised of secondary-growth, deciduous forest with a *Quercus* spp. (oak)-dominated canopy. Forests in our study site, located in the Allegheny Plateau (Hopkins et al. 2014, Miller et al. 2015), are temperate deciduous (Link et al. 2018, Utz et al. 2018), with an average precipitation of about 1000 mm evenly distributed throughout the year (Hopkins et al. 2014). Soils in the reserve (and all 4 riparian corridors) consist entirely of loam and silty loam (USDA 1981) in the Gilpin–Wharton–Weikart group

(PA044, NRCS 2020). Dominant native trees in the reserve currently include *Acer* spp. (maples), oaks, and *Prunus serotina* Ehrh. (Black Cherry) (Utz et al. 2018). Prior to widespread deforestation in the 19th century, forests in the region were dominated by *Carya* spp. (hickories) and oaks (Thompson et al. 2013). Within Eden Hall, forest recovery has been ensuing within all forested parcels following abandonment of horse pastures during the early 20th century. Currently, 10 terrestrial salamander species have been reported from Allegheny County, in addition to a few others historically found there as well as some species found in adjacent counties, but not all are necessarily within our study area (Hulse et al. 2001).

Precedent studies along campus stream valleys led to the observation that the riparian zones were heavily invaded by Japanese Barberry along 2 of the 4 headwater streams present at Eden Hall while only sporadic, isolated patches were found along the 2 others (Marion Holmes, University of Pittsburgh, Pittsburgh, PA, unpubl. data). The invasion status appears to be random and independent of obvious ecological attributes; the forest canopy and age, soils, stream size (all 1st-order headwater), and topographic characteristics are all consistent among riparian zones (R.M. Utz, unpubl. data). We identified 4 stream riparian zones to include in this study: 2 that are currently very heavily invaded by Japanese Barberry, which forms a dense, contiguous, recalcitrant layer that exceeds 90% cover, and 2 where Japanese Barberry is found only in isolated, sporadic patches. Flora in control riparian zones was comprised mostly of native herbaceous species commonly encountered elsewhere in the forest, including *Impatiens* spp., *Symplocarpus foetidus* L (Skunk Cabbage), and *Persicaria virginiana* L. (Jumpseed).

Methods

We placed coverboards made of untreated *Tsuga canadensis* (L.) Carrière (Eastern Hemlock) along the stream riparian zones in the summer and fall of 2017. Initially, 81 coverboards were deployed: 17 and 26 apiece in the 2 invaded stream corridors, and 19 in each of the 2 control stream corridors. Each board covered an area of 0.25 m² and was 2.5 cm thick. We placed coverboards in a staggered pattern on either side of the stream ~4 m away from stream edges at ~17.5-m intervals. Weathering occurred for at least 9 months before we checked the boards in the summer and fall of 2018 and the spring of 2019.

We conducted 3 surveys of salamanders along each riparian zone in the summer/fall of 2018 and a single survey during in the spring of 2019. Some coverboards were not found following deployment, potentially due to disturbance by large-bodied organisms, and we excluded these from analyses. We conducted surveys during daylight hours regardless of weather conditions. We overturned coverboards and caught salamanders by hand for identification to the lowest practical taxon, which was species in most cases except for some individuals in the genus *Desmognathus*. We then returned the coverboards to their original location following surveys and released the salamanders where they were collected.

We also conducted vegetation surveys during the summer 2018 field season. We randomly selected a single 0.25-m² quadrant next to each coverboard to record the

stem diameter and count the number of Japanese Barberry stems. We only counted stems that were rooting in the plot. We then calculated biomass using the following allometric formula (Link et. al. 2018):

$$DM = e^{-2.02 + 1.65 \ln(d)},$$

where DM is dry mass (mg) and d is stem diameter in mm.

We assessed whether salamander abundance was associated with Japanese Barberry invasion using mixed effect, generalized linear models (GLMs) with 3 invasion metrics as independent variables: invasion status (invaded or control), Japanese Barberry biomass density, and Japanese Barberry stem counts. We applied Poisson error distributions since our dependent variable was salamander count per coverboard. We also included the coverboard as a random factor in each model, as sampling efforts involved up to 3 repeat sampling events of the same location. Analyses were conducted in R version 3.5.2 (R Foundation, Vienna, Austria), and mixed-effect GLMs were assessed using the ‘lmerTest’ package (Kuznetsova et al. 2017).

Results

Japanese Barberry cover was much higher in the 2 stream reaches that were classified as invaded, with a mean of about 10 times more Japanese Barberry dry mass per unit area (Fig. 1). Mean Japanese Barberry cover in the 2 control stream riparian zones was heavily skewed by the occasional patch of Japanese Barberry, and 31 control corridor grids (84%) were entirely free of Japanese Barberry invasion.

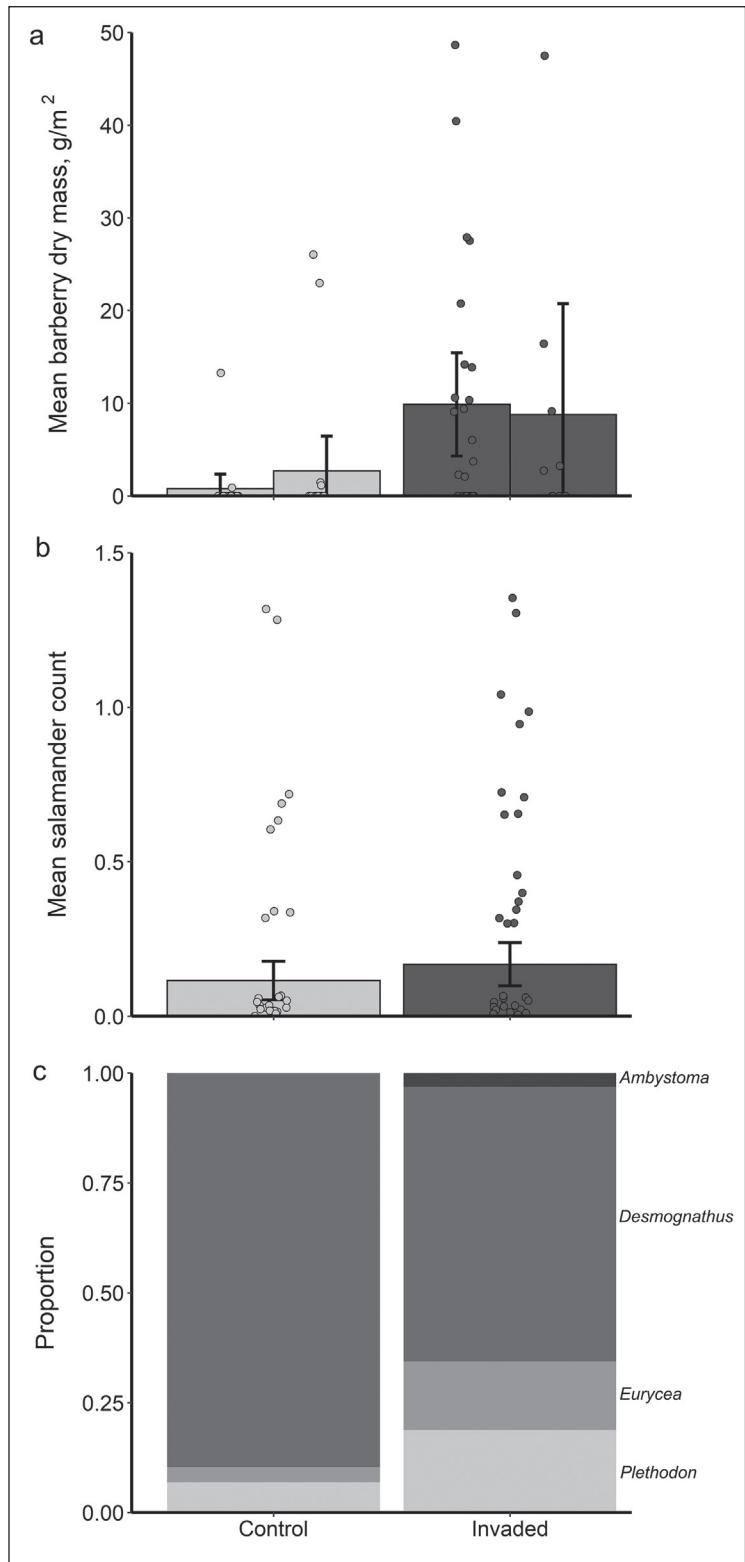
A total of 151 individual coverboard visits (74 in control sites, 77 in invaded) were included in the final dataset after accounting for lost or disturbed replicates. Over the course of the study, 61 salamanders were recorded representing 7 species (Table 1). *Desmognathus* spp. were most encountered, and 15 individuals in this genus were not identifiable to species.

The 3 generalized linear models conducted suggested there were not statistically significant differences between the control and invaded streams or an influence of

Table 1. Total counts of salamander species encountered over the course of the study in each riparian corridor type.

Species	Total	Control corridors		Invaded corridors	
		Site 1	Site 2	Site 3	Site 4
<i>Ambystoma maculatum</i> (Shaw) (Spotted Salamander)	1	0	0	0	1
<i>Desmognathus fuscus</i> (Rafinesque) (Dusky Salamander)	17	8	1	7	1
<i>Desmognathus monticola</i> Dunn (Seal Salamander)	1	0	0	1	0
<i>Desmognathus ochrophaeus</i> (Cope) (Mountain Dusky Salamander)	13	3	3	1	6
<i>Desmognathus</i> spp. (dusky salamanders)	15	11	0	1	3
<i>Eurycea longicauda</i> (Green) (Long-tailed Salamander)	6	1	0	5	0
<i>Plethodon cinereus</i> (Green) (Redback Salamander)	2	0	0	1	1
<i>Plethodon glutinosus</i> (Green) (Slimy Salamander)	6	0	2	4	0

Figure 1. Comparison of (a) *Berberis thunbergii* (Japanese Barberry) abundance at each of the study sites and (b) salamander capture rates under coverboards between site types. Bars represent means, error bars are 95% mean confidence intervals, and dots represent data points. (c) Generic composition of salamander captures between control and invaded sites.



Japanese Barberry invasion intensity and salamander abundance (Table 2, Fig. 1). None of the metrics or categories used to define the degree of Japanese Barberry invasion appeared to affect salamander abundance. Salamander species composition between invaded and control sites significantly varied, with more species diversity encountered in invaded sites.

Discussion

Although our data represent a limited spatiotemporal scale, results suggest that Japanese Barberry invasion along riparian corridors does not strongly influence the abundance of salamanders in our study region. Such findings align with surveys conducted elsewhere that did not find a direct link between salamander abundance and Japanese Barberry invasion (Maerz et al. 2009). The tendency of Japanese Barberry to form dense, monospecific understory layers may somewhat improve upland salamander habitat in some ways, as the additional structure may mitigate high temperatures and maintains elevated humidity via shading (Link et al. 2019). Furthermore, salamander prey may not be affected by Japanese Barberry, as arthropod diversity but not abundance declines and large-bodied detritivore densities rise following invasion (Clark and Seewagen 2019). However, such potential benefits may be balanced by negative indirect effects on salamanders that we did not investigate. For example, Japanese Barberry and other introduced shrubs often co-invade with nonnative earthworms, resulting in diminished leaf-litter layers that can negatively impact salamanders (Maerz et al. 2009; Ziemba et al. 2015, 2016).

Dense growth of invasive plant species can, in some instances, promote the abundance of native herpetofauna (McEvoy and Durtsche 2003). For example, invasive shrub species may promote salamander diversity if species with closely overlapping niches spatially partition habitat by climbing shrub stems (McEntire 2016, Mezebish et al. 2018), though such behavior has not been confirmed in our region and would likely only occur when conditions (i.e., high humidity) allow. Although our data are too spatiotemporally limited to conclude with confidence that such behavior helps to maintain salamander diversity in our study sites, we did detect more diversity within Japanese Barberry-invaded sites. Despite these examples, most studies detect negative effects of invasive plants on amphibians and positive effects only in isolated cases (Bucciarelli et al. 2014).

Consequently, our exploratory survey suggests that Japanese Barberry invasion does not directly negatively impact the abundance, but possibly the diversity,

Table 2. Generalized linear mixed models assessing salamander abundance in association with *Berberis thunbergii* (Japanese Barberry).

Modeled independent variable	Terms for independent variable	
	z-value	P-value
Plot type	0.6	0.540
<i>B. thunbergii</i> stems	-0.4	0.670
<i>B. thunbergii</i> dry mass	0.1	0.889

of salamanders in North American eastern deciduous forests. Unequivocally determining how invasive plants impact herpetofauna would require more data than we present here, as effects may not be detected for years following an invasion (Brown et al. 2006). Furthermore, invasive plants may indirectly positively (Mezebish et al. 2018) or negatively affect amphibian populations via pathways such as trophic cascades or habitat provisioning. Therefore, our results offer cautious optimism that at least 1 pervasive invasive shrub may not directly reduce forest-dwelling amphibians, but conclusively determining holistic impacts of such invasions will require additional research.

Acknowledgments

We would like to thank Chatham University for providing the space and funding for this project. We are grateful for Arianna Allen, Gabriela Briceño, Kayla Conklin, Joe Geever, Daniel Kline, Fabiana Licata, Michael Nelson, Quentin Rice, Allison Stein, Cierra Snyder, and Trey Turnblacer for assistance in the field. This study was performed under the auspices of the Chatham University Animal Care and Use protocol number CHA013.2017.

Literature Cited

- Adams, C.K., and D. Saenz. 2012. Leaf litter of invasive Chinese Tallow (*Triadica sebifera*) negatively affects hatching success of an aquatic breeding anuran, the Southern Leopard Frog (*Lithobates sphenoccephalus*). *Canadian Journal of Zoology* 90:991–998.
- Brown, C.J., B. Blossey, J.C. Maerz, and S.J. Joule. 2006. Invasive plant and experimental venue affect tadpole performance. *Biological Invasions* 8:327–338.
- Bucciarelli, G.M., A.R. Blaustein, T.S. Garcia, and L.B. Kats. 2014. Invasion complexities: The diverse impacts of nonnative species on amphibians. *Copeia* 2014:611–632.
- Clark, R. E., and C.L. Seewagen. 2019. Invasive Japanese Barberry, *Berberis thunbergii* (Ranunculales: Berberidaceae) is associated with simplified branch-dwelling and leaf-litter arthropod communities in a New York Forest. *Environmental Entomology* 48:1071–1078.
- Earl, J.E., K.E. Cohagen, and R.D. Semlitsch. 2012. Effects of leachate from tree leaves and grass litter on tadpoles. *Environmental Toxicology and Chemistry* 31:1511–1517.
- Hopkins, K.G., D.J. Bain, and E.M. Copeland. 2014. Reconstruction of a century of landscape modification and hydrologic change in a small urban watershed in Pittsburgh, PA. *Landscape Ecology* 29:413–424.
- Hulse, A.C., C.J. McCoy, and E.J. Censky. 2001. *Amphibians and Reptiles of Pennsylvania and the Northeast*. Cornell University Press, Ithaca, NY. 419 pp.
- Kuznetsova, A., P.B. Brockhoff, and R.H.B. Christensen. 2017. lmerTest package: Tests in linear mixed effects models. *Journal of Statistical Software* 82:1–26.
- Link, A.F., T. Turnblacer, C.K. Snyder, S.E. Daugherty, and R.M. Utz. 2018. Low recruitment of native trees in a deciduous forest associated with Japanese Barberry (*Berberis thunbergii*) invasion. *Invasive Plant Science and Management* 11:20–26.
- Link, A.F., L. Johnson, and R.M. Utz. 2019. To manage or not? Successful native tree seedling restoration despite a dense, invasive shrub, *Berberis thunbergii*. *Plant Ecology* 220:577–593.
- Maerz, J.C., V.A. Nuzzo, and B. Blossey. 2009. Declines in woodland salamander abundance associated with non-native earthworm and plant invasions. *Conservation Biology* 23:975–981.

- McEntire, K.D. 2016. Arboreal ecology of Plethodontidae: A review. *Copeia* 104:124–131.
- McEvoy, N.L., and R.D. Durtsche. 2003. The effect of invasive plant species on the biodiversity of herpetofauna at the Cincinnati Nature Center. *Norse Scientist* 1:51–55.
- Mezebish, T.D., A. Blackman, and A.J. Novarro. 2018. Salamander climbing behavior varies among species and is correlated with community composition. *Behavioral Ecology* 29:686–692.
- Miller, R., J. Wisgo, J. McPherson, E. Chapman, D. Rihel, D. Sheppard, M.A. Furedi, and C. Tracey. 2015. Assessment of high value ecological areas in Pennsylvania's shale region. Western Pennsylvania Conservancy, Pittsburgh, PA. 124 pp. Available online at <https://waterlandlife.org/wp-content/uploads/2018/02/Assessment-of-High-Value-Ecological-Areas-in-PA-Shale-Region-2015.pdf>.
- Natural Resources Conservation Service, United States Department of Agriculture (NRCS). 2020. US General Soil Map (STATSGO2). Available online at <https://sdmdataaccess.sc.egov.usda.gov>. Accessed 23 January 2020.
- Nuzzo, V.A., J.C. Maerz, and B. Blossey. 2009. Earthworm invasion as the driving force behind plant invasion and community change in northeastern North American forests. *Conservation Biology* 23:966–974.
- Thompson, J.R., D.N. Carpenter, C.V. Cogbill, and D.R. Foster. 2013. Four centuries of change in northeastern United States forests. *PLOS ONE* 8:e72540.
- United States Department of Agriculture, Soil Conservation Service (USDA). 1981. Soil survey of Allegheny County, Pennsylvania. 103 pp. Available online at: https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/pennsylvania/PA003/0/allegheny.pdf. Accessed 23 January 2020.
- Utz, R.M., T.A. Pearce, D.L. Lewis, and J.C. Mannino. 2018. Elevated native terrestrial snail abundance and diversity in association with an invasive understory shrub, *Berberis thunbergii*, in a North American deciduous forest. *Acta Oecologica* 86:66–71.
- Vilà, M., J.L. Espinar, M. Hejda, P.E. Hulme, V. Jarošik, J.L. Maron, J. Pergl, U. Schaffner, Y. Sun, and P. Pyšek. 2011. Ecological impacts of invasive alien plants: A meta-analysis of their effects on species, communities and ecosystems. *Ecology Letters* 14:702–708.
- Watling, J.I., C.R. Hickman, E. Lee, K. Wang, and J.L. Orrock. 2011a. Extracts of the invasive shrub *Lonicera maackii* increase mortality and alter behavior of amphibian larvae. *Oecologia* 165:153–159.
- Weidenhamer, J.D., and R.M. Callaway. 2010. Direct and indirect effects of invasive plants on soil chemistry and ecosystem function. *Journal of Chemical Ecology* 36:59–69.
- Williams, S.C., and J.S. Ward. 2010. Effects of Japanese Barberry (Ranunculales: Berberidaceae) removal and resulting microclimatic changes on *Ixodes scapularis* (Acari: Ixodidae) abundances in Connecticut, USA. *Environmental Entomology* 39:1911–1921.
- Ziemba, J.L., A.C. Cameron, K. Peterson, C.-A.M. Hickerson, and C.D. Anthony. 2015. Invasive Asian earthworms of the genus *Amyntas* alter microhabitat use by terrestrial salamanders. *Canadian Journal of Zoology* 93:805–811.
- Ziemba, J.L., C.-A.M. Hickerson, and C.D. Anthony. 2016. Invasive Asian earthworms negatively impact keystone terrestrial salamanders. *PLOS ONE* 11:e0151591.