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A METHOD FOR CONTROL OF *EUONYMUS FORTUNEI* USING ROUNDUP PRO® (GLYPHOSATE)

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Wintercreeper, *Euonymus fortunei* (Turcz.) Hand.-Mazz., is an invasive exotic plant that infests and overruns many wooded areas. It can totally carpet forest understories preventing the growth of any new plants of other species. The scarce literature (Miller, 2002, 2003; Moorhead, 2005) and other information (J. T. Miller, pers. comm.) on methods for control of *E. fortunei* stresses the use of the chlorinated pyridine herbicides Garlon® (generic name Triclopyr) and Tordon® (generic name Picloram). However, the use of these two broad spectrum herbicides is not favored in many applications and is not tolerated politically in many communities, especially when *Euonymus* grows on public lands. Glyphosate (originally sold under the Roundup® name) is also a broad spectrum herbicide, but its ability to bind to the soil and its lack of longterm stability in the environment, combined with the fact that it does not run off into streams, make it more acceptable in many communities. However, glyphosate has generally been relegated to third choice as an option in treating *Euonymus*, apparently because reliable methods for its use with this plant have not been developed or because multiple applications of the herbicide have been reported to be required. Cutting the leaves and stems of *E. fortunei* prior to spraying with glyphosate has also been recommended, but this entails another step that many site managers are reluctant to undertake and, in any case, the utility of this extra step has not been established. Rogers and Schulz (2005) have recently explored this practice more thoroughly, but details of their work are not currently available.

APPROACH TO THE CONTROL PROBLEM

The present study of the use of glyphosate for the control of *E. fortunei* was conducted in Ruth Park Woods in University City, MO. This woods has many large areas where *E. fortunei* has entirely covered the ground and no other species are present, other than mature deciduous trees.

A few overriding conditions guided our decision on the timing of the operation: 1) We wanted to avoid spraying in the early months of the growing season so as to avoid harming spring ephemerals; 2) We also wanted to have actively growing plants, but under conditions where we could be assured of a few days in a row without rainfall; 3) Lastly, we wanted to be certain that there would be at least one month until the first killing frost.

We also decided that this study would be a basic study of the effect of glyphosate on wintercreeper without the interference of outside agents. This meant avoiding the problem that would be caused by having a great number of fallen tree leaves on top of the plants. It also meant that we would not do any precutting of the leaves and/or stems. These considerations all pointed to conducting the study in early September. The choice proved to be fortuitous.

METHODS

Test plots of 6 ft × 8 ft (2.4 m × 1.8 m) each were laid out in an area of lush, long-established growth of *E. fortunei*. The surrounding growth functioned as the experimental control. Any fallen deciduous leaves on top of the plants were removed by hand.

Roundup PRO® was supplied as ca. 40% glyphosate concentrate by the University City Forestry Department. It was diluted with water to the nominal experimental concentrations in one gallon plastic milk jugs. To avoid excessive foaming due to the surfactant present in the concentrate, water was placed in the jugs first to within 10–15 ounces of the top. Then the concentrate was added, followed by Turfmark dye, followed by additional water so that only a few ounces of space was left at the top. This space was left to allow for mixing.

The author did not have access to accurate laboratory graduated cylinders for measuring the amount of concentrate to be diluted. Instead, we resorted to using kitchen measuring cups. For a concentration of 1.5% in 1 gallon, 142 ml of 40% concentrate is needed. We measured 150 ml in the measuring cup and poured that into the jug without rinsing out the cup. This left a few ml in the cup at all times. With some material left in the cup and some space in the top of the jug for mixing, the final concentration, while nominally 1.5%, was probably in the range of 1.5–1.65%. Similar measurements and additions were made for the nominal 2.0%, 3.0%, and 6.0 % materials, although the last two were done in ½ gallon jugs.

The days for spraying were selected based on weather forecasts of no rain for at least 24 hours and preferably longer. Spraying was done using one gallon polyethylene plastic sprayers manufactured by Gilmour Manufacturing Company, Somerset, PA. The area to be treated was sprayed until all leaves were visibly wet, but not dripping. This amounted to about ⅛ gallon (1 pint, 470 ml) per 6 ft × 8 ft (2.4 m × 1.8 m) plot each time every plot was treated. The manner of spraying all plots was as closely identical as possible for all treatments.

The intense overlap of root systems and stems, both horizontally and vertically, in the wintercreeper test plots prevented the employment of the conventional technique of judging percent kill. This would have involved counting individual live stems before spraying and then counting individual live stems after the test period. Instead, the author made a visual judgement of how much green area remained within each plot at selected times after the spraying.

RESULTS AND DISCUSSION

Results for the spraying are presented in Table 1. The initial work on 5 September 2003 showed that even with only 1.5% glyphosate as Roundup Pro® one could attain excellent kill if one was patient enough to wait for the full effect. Plot 2 shows this conclusively. Only two days of spraying were required if one waited 18 months for all the wintercreeper to die. Similar results were obtained after only 12 months using 3 days of spraying in plot 3. In all cases the control plants surrounding the individual plots appeared perfectly normal, with lush growth throughout, during the entire test period.

The cost and effort of any exotic control program is a combination of herbicide costs and worker time. In many cases the latter is a more important factor than the former, even with

Table 1. Results for Spraying *Euonymus fortunei* with Roundup Pro®.

Plot #	September 5, 2003 Spraying	6–7 months	12 months	18 months
1	1.5% one day	25–30%	50%	85–90%
2	1.5% once per day for 2 consecutive days	50–60%	90–95%	99%
3	1.5% once per day for 3 consecutive days	85–90%	98%	99%
4	1.5% once per day for 4 consecutive days	85–90%	98%	99%
Plot #	September 20, 2004 Spraying	6–7 months	12 months	
5	6% one day	90%	95%	
6	3% once per day for 2 consecutive days	95%	98%	
7	3% one day	50%	90%	
8	2% once per day for for 3 consecutive days	90%	98%	
9	2% once per day. for 2 consecutive days	40%	80%	
10	2% one day	40%	60%	
11	2% one day; repeat 1 month later	90%	90%	
12	2% one day; repeat 7 months later	30%	99%	
13	2% one day; repeat 1 month later and then 7 months after first spray	98%	99%	

volunteer workers. Thus, in 2004, we decided to expand our work to higher concentrations of glyphosate to see if the excellent kill observed in 12 months with 3 sprayings of glyphosate could be accomplished with only 1 or 2 sprayings.

Plot 6 illustrates that one could indeed accomplish this goal, although at the cost of using a 3% solution. The results with 2% solution were less clearcut, although extenuating circumstances might have played a major role (see below). Plot 12 was quite successful giving 99% kill with an initial spray in September and the second the following April. The anomalous result in this group is plot 9, where spraying for 2 consecutive days with 2% solution afforded poorer results than the previous year's work with 1.5% solution.

Two things may have had a great effect on the 2004 sprayings. For one, the work was performed 15 days further into the fall and the plants might have been closer to winter dormancy. More importantly, from late August through the end of September 2004 was a period of intense drought in the St. Louis region and many other species of plants were showing signs of extreme wilt at the time the wintercreeper was sprayed. Even though the target plants showed no visible effect of the drought, it is very likely that they were affected enough to inhibit the normal uptake of glyphosate. This could explain the anomalous result with plot 9.

The critical timing of the spraying was illustrated by the work of a colleague, Malinda Slagle (pers. comm.). Upon hearing of our work she undertook the spraying of wintercreeper with a different supply of glyphosate (Gly Star Plus®) at the Litzsinger Road Ecology Center in the fall of 2004. She applied about four times as much solution as we did, but achieved only 30–50% kill in plots sprayed in November. Her single September plot was as successful as our work in September. This supports our original premise that spraying a considerable time before the onset of winter dormancy is important if one is to achieve significant kill of *E. fortunei.*

Strictly speaking, our results apply only to the use of Roundup PRO®. It is likely that other formulations of glyphosate will work as well. However, at this point it is difficult to pinpoint how the differences among formulations will affect the final results. Roundup PRO® is guaranteed rainfast after 6 hours. It also contains a significant amount of surfactant. It is likely that other formulations containing surfactant and with some degree of rainfastness will also work well. One such example is Roundup Weed & Grass Killer which is aimed at the retail consumer. It is rainfast within 2 hours of application.

The companies that formulate glyphosate, including Monsanto, may change the individual contents from time to time. These could include adding adjuvants, changing the salt form of the glyphosate or changing types and quantities of the surfactants. It would be best to test any formulations other than Roundup PRO® first and then, if success is found in the test, proceed to larger scale applications the following season. We plan to test some other formulations in the fall of 2006.

EXTREME DELAYED LETHALITY

One of the potentially most interesting points to emerge from this project is the apparent extreme delay in lethal effects from Roundup, at least in this species. Lethality in herbicide applications is generally judged in terms of a few months at most, whereas our results show that 12–18 months may be required for almost complete elimination of *E. fortunei.* If this is true for other species as well, many treatments that have been rated as failures may indeed be ultimately successful. In particular this may apply to other species that have leaves with a very waxy surface.

ACKNOWLEDGMENTS

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ECOLOGY OF THREE POPULATIONS OF THE RARE WOODLAND PERENNIAL, *TRILLIUM PUSILLUM* MICHAUX (LILIACEAE), IN SOUTHWESTERN MISSOURI

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Trillium pusillum Michx. (incl. var. *ozarkanum* (E.J. Palmer & Steyerm.) Steyerm.), the Ozark wake robin, is a perennial, woodland spring ephemeral that blooms in Missouri in late March or early April and fruits and senesces in early July. The species was formerly considered federally for listing as an endangered species, is listed as category S2 of conservation concern in Missouri by the Missouri Natural Heritage Program (Missouri Natural Heritage Program, 2006), and is considered to be imperiled in all five of the states where it grows. It is believed to be limited to 17 sites in Missouri.

As a member of the spring ephemeral guild, *T. pusillum* is a potentially important component of Ozark woodlands. Spring ephemerals provide nectar and pollen to pollinators early in their above ground season when few other plants are in bloom, and they function as a "vernal dam" by temporarily sequestering nutrients and preventing leaching from forest systems during a period of high nutrient availability (Vitousek and Reiners, 1975; Bormann and Likens, 1979; Blank et al., 1980; Hedin et al., 1995; Anderson and Eickmeier, 2000; Anderson, 2004).

Trillium pusillum habitat in Missouri has only been described in general terms, such as "mesic to dry-mesic upland forests on gentle slopes, usually in cherty soils on calcareous substrates" or

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as occurring on a "gentle west-facing slope [with] shallow cherty soils" (Yatskievych, 1999; Morgan and Wallace, 1987). A site in Barry County in southwestern Missouri studied by Morgan and Wallace (1987) was described as an oak-hickory woodland with flowering dogwood (*Cornus florida*) as the dominant subcanopy species; the dominant spring-flowering herbaceous species included *Anemonella thalictroides, Podophyllum peltatum, Dentaria laciniata, Erythronium albidum,* and *Viola* sp.

The growth of *Trillium* consists of three major stages: one-leaved, three-leaved, and flowering (Ohara and Kawano, 1986; Kawano et al., 1986; Ohara and Utech, l986). The stage structure that would result in a stable, viable population was described by Morgan and Wallace (1987) for a *T. pusillum* population in Barry County, Missouri. Morgan and Wallace's stable population, (determined by counting all plants in one 25 m^2 plot), was 159 one-leaved stems, 89 three-leaved stems and 14 flowering stems (see Fig. 1). The number of flowering stems increased from 14 to 48 during the three year period of the study and the authors concluded that this population would probably increase in size or at least remain stable.

Our study was undertaken to survey the current and possible future status of *T. pusillum* in southwestern Missouri. We surveyed three populations in 2001 and 2002, hereafter referred to as the *Baker, Heckmaster*, and *Hoover Woods* sites. Population size and stage structure, along with pollinator visitation and seed dispersal, were determined to assess population viability. In addition, plant community structure (species composition, species diversity, cover) and general habitat characteristics (canopy light penetration, soil moisture and pH) were related to population viability. This study contributes to a general biological and ecological knowledge of this rare species in Missouri and identifies some habitat conditions that vary at sites where the *T. pusillum* population is viable vs. contracting; and therefore, contributes to future conservation and/or restoration efforts on behalf of this species.

METHODS

GENERAL DESCRIPTION OF *T. PUSILLUM*.—*Trillium pusillum* has been described by Freeman (1996), Timmerman-Erskine (1999), Timmerman-Erskine et al. (2002a, b, 2003), and Yatskievych

(1999) as a perennial with one or more glabrous, erect, aerial stems arising from a short, horizontal rhizome. Each stem when mature has one terminal, actinomorphic flower, which is borne above the whorl of three leaves on a pedicel up to five centimeters long. The flower has three, free, oblong, white petals turning pink to rose as the flower ages. There are three herbaceous green sepals and three styles, these united at the base and elongating through the six stamens as the flower matures, with the stigmatic branches slowly separating and recurving. The ovary is superior, with three locules, each producing numerous ovules. The fruit is an erect, green berry that abscises basally from the receptacle to disperse eventually into the leaf litter, sometimes with all seeds remaining inside. The seeds are shiny, dark brown, and relatively large, each with a white fleshy aril developing from the cells at the upper part of the raphe and at maturity covering the hilum.

REPRESENTATIVE SPECIMENS.—**Barry County.** Hoover Woods site in woods at base of slope under city of Cassville water towers. 36°40.52'; 93°52.31', elevation 414 m, 21 April 2002, Andre *128* (SMS 65838). **Barry County.** Baker site east of Cassville. 36°41.39'; 93°50.58', elevation 414 m, 21 April 2002, *Andre 129* (SMS 65827). **Lawrence County.** Heckmaster site east of Friestatt. 36°00.53'; 93°50.32', elevation 396 m, 24 April 2002, *Andre 130* (SMS 65826).

STUDY SITES.—Study sites were found by examining Element Occurrence Records of the Missouri Department of Conservation's Natural Heritage Database, contacting botanists and landowners, and driving surveys in Barry and Lawrence counties. Of the 16 populations of *T. pusillum* known to the authors at the time, at least 8 were already extirpated or reduced to only a few flowering stems in 2001 when the study began. The three sites where populations were examined were named generically or with reference to historic names in the Heritage Database.

The Baker site is believed to be "Source 7" of the seven Wildwood North populations (sources) in the records of the Missouri Natural Heritage Database and is the largest of the three sites selected for this study. There are no historical data on population size for Source 7. The site is open woodland on a west-facing slope located in eastern Cassville in Barry County. The site is an irregularly shaped area of ca.13,500 m^2, which is fenced on three sides and bordered by woods on all four sides. There are two soil types within the site. The upper half of the slope (9–14%

incline) is Clarksville-Noark and is described as well drained and very friable, very gravelly silt loam, subsoil to 152.4 cm (Aldrich and Meinert, 1994). The soil type on the lower half of the slope (ca. 35% incline) is Clarksville, which is described as somewhat excessively well drained. There has been no harvesting of timber or major disturbance to this site during the last 58 years (Barbara McClure, pers. comm.), although cattle have had constant access to this area throughout that time. Cattle were evident at the site during the first year of the study, when their trampling in the area resulted in the loss of some plants near the top of the slope. *Trillium pusillum* was found scattered throughout this site, but primarily on the mid- to lower portions of the slope. The most abundant growth was located at the northwestern corner in the lower third of the slope.

The Hoover Woods site is also in Barry County. It is within the city limits of Cassville. The site has a north-facing slope with an incline ranging from 14% at the bottom to 35% near the top. It has been undisturbed since 1945 (Gerry Hoover, pers. comm.). History prior to 1945 was not available. The site is ca. 4,000 m^2 and the soil type is classified as Clarksville (Aldrich and Meinert, 1994). Numerous signs of deer were noted on this site and one group of eight deer was observed during one visit. An invasive exotic evergreen vine, *Euonymus fortunei*, covers much of the ground and tree trunks at this site. Heritage Database occurrence records indicate there were approximately 2,000 plants in 1981 and 300-400 scattered stems (flowering and sterile) in 1994. We found *T. pusillum* only in ca.144 m^2 area of the lower eastern portion of the site in 2001 and 2002. Flowering stems were found scattered in the sampling area in April 2001, but could not be located to be counted when the site was visited again in early May. In 2002, 87 stems (30 flowering) were found in a ca.9 m^2 area at the base of the slope under some shrubs, but only three flowering plants were found scattered in the rest of the area.

The Heckmaster site is the northernmost known population for this taxon and is located in Lawrence County, ca. 30 miles north of Cassville. The soil type at the site is Clarksville-Nixa, a cherty silt loam, 5 to 14 percent slopes (Hughes, 1982). There has been no disturbance to this land for about 80 years (Donald Heckmaster, pers. comm.). This site may be the "Spring River Tributary" site noted in Heritage Database records. In 1984, the population of *T. pusillum* at the Spring River Tributary site was described as "130 and 50 plants in two separate patches". In 2002, we found *T. pusillum* throughout the 1,000 m^2 site, with the most abundant growth, approximately 500–600 flowering stems, occurring within 100 m^2 at the bottom of the slope (14% incline).

DEMOGRAPHY AND REPRODUCTIVE POTENTIAL.—Population sizes, density and dispersion were estimated from surveying the entire area of each site, where the area of the site was bounded by the spread of the species across the site, and by estimating from counts within permanent 1 m^2 plots (see below). Stage structure at each site was determined by using transects and permanent points along the transects. A transect was run across each site either above or below the slope and perpendicular to it. At random points along each transect, perpendicular transects were run up or down the slope (Baker n=5; Heckmaster n=4; Hoover Woods n=3). Permanent points were then established by random selection along each transect on the slopes and marked using metal spikes and flags (Baker n=45; Heckmaster n=20; Hoover Woods n=15). Stems in each stage—unifoliate, trifoliate, and flowering—were counted within 1 m^2 plots around each point.

Preliminary observations of floral visitors of *T. pusillum* were made at each site in early April 2002. Sites were observed for one hour in mid-morning, one hour in mid-afternoon and for one hour during early evening.

To assess the number of seeds per fruit, berries were randomly gathered at Baker and Heckmaster in 2001 and 2002 and at Hoover Woods in 2002 (Baker n=10; Heckmaster n=11; Hoover Woods n=5). Seeds were counted and seeds and elaiosomes were weighed to the nearest 0.0000 grams (Baker=26; Heckmaster=25; Hoover Woods=30).

To assess dispersal, seed depots were created (Baker n=11; Heckmaster n= 6; Hoover Woods n=2) by clearing the leaf litter from 100 cm^2 areas. Ten seeds were placed in each depot. Each seed depot was observed for one hour during the late morning or early afternoon.

COMMUNITY AND HABITAT CHARACTERISTICS.—Tree species >5 cm dbh were surveyed in May 2001 using a point quarter method (Barbour et al., 1999). Trees were also surveyed together with shrubs and woody vines in May 2002 in randomly placed 25 m^2 plots. Herbaceous plant cover was surveyed in randomly placed 1 m^2 plots in April and May 2002. In addition, a species list was maintained of all plants observed at each site from late March through early July of 2001 and 2002 (see Appendix 1, 2).

We used leaf area index (LAI), which is the ratio of the total area of all leaves on a plant to the area of ground covered by the plant (Barbour et al., 1999), as a measurement of canopy light penetration (CLP). Based on the inverse relationship of LAI and CLP, we defined CLP as: CLP=12 – LAI.

CLP was determined by measuring the photosynthetically active radiation (PAR) above the tree canopy and at approximately 15 cm above the ground using an Accupar (Decagon Devices, Inc., PAR-80). Areas with a low CLP are shady; areas with a high CLP are sunny. Measurements were taken at each site in May 2001 (Baker n=36; Heckmaster n=20; Hoover Woods n=15), in March 2002 (Baker n=62; Heckmaster n=39; Hoover Woods n=15), and in June 2002 (Baker n=25; Heckmaster n=13; Hoover Woods n=15).

Soil samples were collected twice at a depth of ca. 6–8 cm, approximating the depth of the trillium rhizomes, using a stratified random sampling technique to gather samples from different areas on the slopes and across each site (Baker n=9; Heckmaster n=5; Hoover Woods n=6). Samples were sent to the University of Missouri Soil Laboratories for analysis of pH or dried at 100° C for gravimetric determination of soil moisture.

RESULTS and DISCUSSION

DEMOGRAPHY AND REPRODUCTIVE POTENTIAL.—Based on current estimated population sizes and density (Table 1), historical population sizes, and stage structures (Fig. 1) it appears that *T. pusillum* populations in southwestern Missouri have to be large and clumped to be viable in the long-term. Both the Baker and Heckmaster sites had populations greater than 1,000 stems, whereas the Hoover Woods site had a population of less than 100 stems (Table 1). The Heckmaster population is very dense within a relatively small area, but the Baker and Hoover Woods populations are sparse (Table 1), with the caveat that the Hoover Woods population is essentially one small clump (see Methods).

Table 1. Population characteristics for *Trillium pusillum* at three sites in southwestern Missouri and related community and habitat characteristics. Means are followed by standard deviations (±).

Population Variable	Baker	Heckmaster	Hoover Woods
Population size (n)	6,900	6,500	90
Total density/site (m^{-2})	0.51	6.5	0.02
Mean density/plot (m^{-2})	5.3±1.9	15.8±12.5	6.0±3.0
Sequential pollinator visitation per stem (%)	55	69	0
Mean seeds/capsule (#)	18.5±9.2	11.0±4.8	17.8±6.5
Mean seeds dispersed/depot (#)	7.0±2.9	6.0±4.0	10±0.0
Canopy tree density (#/hectare)	891	443	1391
Herbaceous cover (%)	41	29	82
Mean canopy light penetration	8.7±2.3	9.5±1.4	6.9±4.5
Mean soil moisture (%)	4.5±0.8	5.1±1.0	7.5±0.2
Soil pH	6.1	5.9	6.5

Based on previous unpublished census records it appears that the population at Heckmaster has grown substantially since recorded populations in 1984 (approximately 180 stems), but the population at Hoover Woods has declined since 1981 (2,000 stems) and 1994 (300–400 stems) censuses. The Heckmaster population has a stable stage structure and is predicted to expand, whereas both the Baker and Hoover Woods populations have unstable stage structures and are predicted to decline (Fig. 1) (Kawano et al., 1986). However, the population at Baker may increase in the short-term due to the high percentage of three-leaved stems. In fact, over the two year period the number of flowering individuals increased by only 6% at the Baker site but increased by 57% at the Heckmaster site.

The primary apparent pollinator observed at all three sites was honey bees (*Apis mellifera*), which, based on sequential visitation to stems, were effective pollinators at the Baker and Heckmaster sites, but not the Hoover Woods site (Table 1). Therefore, outcrossing is apparently limited at Hoover Woods. Few native insect pollinator species were observed sequentially visiting flowers. These observations indicate that if honey bees were to decline (e.g., due to tracheal and varroa mites) *T. pusillum* might effectively lose its ability to outcross at our study sites.

There was no strong indication that reproductive output varied among sites, as seed number per capsule (Table 1) and seed weight (data not shown) did not vary significantly between populations

(P>0.05, one-way Analysis of Variance). Nor was there apparent seed dispersal limitation at any site (Table 1). Lower dispersal at higher density sites is expected based on disperser satiation (Smith et al., 1989). However, seed predation may contribute to the low population size at Hoover Woods; at the Baker and Heckmaster sites ants dispersed 100% of the seeds, but at the Hoover Woods site harvestmen dispersed 30% of the seeds. This is significant because harvestmen may consume or damage the seed or leave it wherever the elaiosome is eaten; ant dispersed seeds, by contrast, are generally deposited in nests or nearby in the ants' refuse piles providing nutrients and/or protection from predators (Culver and Beattie, 1980: Beattie and Culver, 1983).

COMMUNITY AND HABITAT CHARACTERISTICS.—There appear to be some clear relationships between plant community characteristics and population size and density of *T. pusillum*. The density of *T. pusillum* was greatest at the site with the lowest density of canopy (and subcanopy) trees (Table 1), and lowest at the site with the highest density of canopy trees. In addition, both the Heckmaster and Baker sites are dominated by *Quercus velutina* and *Carya* spp., whereas Hoover Woods has less than 10% *Quercus* spp. with over 20% of the canopy dominated by *Juglans nigra*.

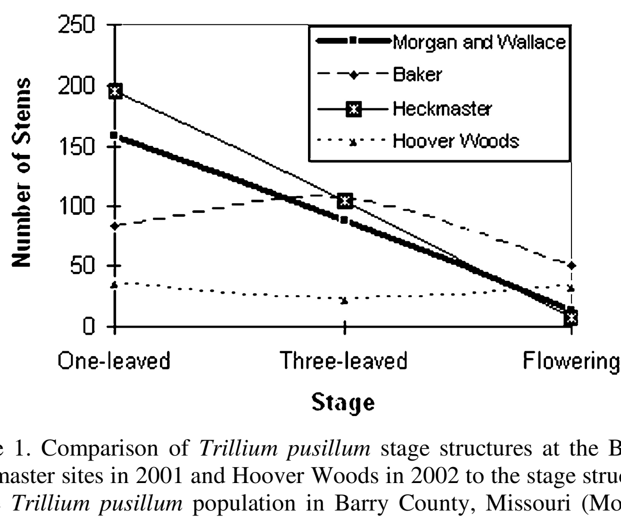

Figure 1. Comparison of *Trillium pusillum* stage structures at the Baker and Heckmaster sites in 2001 and Hoover Woods in 2002 to the stage structure of a viable *Trillium pusillum* population in Barry County, Missouri (Morgan and Wallace, 1987).

Herbaceous cover was two times greater at the Hoover Woods site than at the Baker or Heckmaster sites (Table 1), largely due to the invasion of *Euonymus fortunei* at that site. These data suggest that in Missouri *T. pusillum* is most expected in oak dominated habitats with a relatively low density of herbaceous cover. Lists of all tree and forb species at the sites are included in Appendices A and B.

In addition, a very dense overstory leading to low canopy light penetration is apparently not suitable for viable *T. pusillum* populations. Canopy light penetration averaged over the entire growing season was highest at the Heckmaster site and lowest at the Hoover Woods site (Table 1). However, during anthesis Hoover Woods had the greatest canopy light penetration, which might suggest that high light early in the season may have a negative effect on population growth—and that overstory species identity and phenology is an important characteristic of communities that can support viable *T. pusillum* populations.

The bulk soil analysis of each site indicated high levels of organic matter compared to other Ozark sites (Gaylord Moore, pers. comm..), with pH ranging between 5.9–6.5. Both soil moisture and pH were greatest at the site with a declining population (Hoover Woods) (Table 1). The range of optimal moisture levels has been suggested to be quite narrow for *T. pusillum* (Freeman, 1996), and Hoover Woods soil moisture may be higher than suitable due to the dense overstory canopy.

SUMMARY

This study indicates that *T. pusillum* populations may not be viable in habitats where there is a high soil pH, low light levels associated with high tree density, and the presence of an exotic invasive such as *Euonymus fortunei.* Other variables related to a contraction of *T. pusillum* include pollinator limitation, a change in seed dispersers, and increased herbivory by deer (Augustine and Frelich, 1998; Knight, 2004). Although the data reported here offer some clues to factors responsible for the decline of certain populations of *T. pusillum*, further data are needed to preserve this species in Missouri. In addition to expanding the study to other populations in the future, data are particularly needed on its breeding systems, seed predation, moisture requirements, and, if it outbreeds, its pollinators in non-fragmented forests. For the

remaining populations in Missouri, which largely grow on slopes unsuitable for development, the greatest threats to *T. pusillum* populations appear to be from changes in the habitat, including invasive exotics and, if it primarily outbreeds, overdependence on honey bees (*Apis mellifera*), whose populations are threatened by parasitic mites.

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Appendix A. Checklist of trees, shrubs and woody vines at Baker (Site 1), Hoover Woods (Site 2), and Heckmaster (Site 3).

Site #			Scientific Name
1			*Acer negundo* var. *negundo*
1			*Acer saccharum*
1			*Amelanchier arborea*
1			*Campsis radicans*
1	2	3	*Carya cordiformis*
1			*Carya texana*
		3	*Carya tomentosa*
1		3	*Celtis occidentalis*
1			*Cornus florida*
1	2	3	*Corylus americana*
	2		*Euonymus alatus*
1	2	3	*Euonymus atropurpureus*
1	2		*Euonymus fortunei*
1	2	3	*Juglans nigra*
1		3	*Juniperus virginiana*
1	2		*Lonicera japonica* var. *japonica*
1			*Morus rubra*
1			*Nyssa sylvatica* var. *sylvatica*
1	2	3	*Parthenocissus quinquefolia*
1		3	*Prunus serotina* ssp. *serotina*
1		3	*Quercus alba*
	2		*Quercus muehlenbergii*
1			*Quercus stellata*
1		3	*Quercus velutina*
1			*Rhamnus caroliniana*
1			*Rhus aromatica*
1			*Rhus copillina* var. *latifolia*
1	2	3	*Ribes missouriense*
1	2	3	*Rosa multiflora*
1	2	3	*Rubus* spp.
1	2	3	*Sassafras albidum*
1	2	3	*Smilax* spp.
1	2	3	*Symphoricarpos orbiculatus* f. *orbiculatus*
1	2		*Toxicodendron radicans* spp. *negundo*
1			*Ulmus alata*
1		3	*Ulmus rubra*
1			*Vaccinium* spp.
1	2	3	*Vitis* sp.
	2		*Vitis vulpina*

Appendix B. Checklist of spring and early summer forbs at Baker (Site 1), Hoover Woods (Site 2) and Heckmaster (Site 3).

Site #			Scientific Name
	2		*Adiantum pedatum* var. *pedatum*
1			*Asclepias quadrifolia*
1	2		*Asplenium platyneuron*
1		3	*Botrychium virginianum* var. *virginianum*
1			*Cimicifuga racemosa*
1			*Claytonia virginica*
1			*Dentaria laciniata*
1		3	*Desmodium* spp.
	2		*Dioscorea quaternata*
1			*Dodecatheon meadia*
1			*Erythronium albidum*
1			*Eupatorium rugosum* var. *rugosum*
1			*Galium arkansanum*
1		3	*Galium virgatum*
1	2	3	*Galium aparine*
1	2	3	*Geranium maculatum*
1		3	*Geum canadense* var. *camporum*
		3	*Ipomoea purpurea*
1		3	*Isopyrum biternatum*
1		3	*Lamium purpureum* var. *purpureum*
		3	*Lactuca serriola* f. *serriola*
	2		*Lonicera japonica* var. *japonica*
1			*Maianthemum racemosum* ssp. *racemosum*
1			*Monarda fistulosa*
	2		*Osmorhiza longistylis*
1			*Oxalis violacea*
1			*Parietaria pensylvanica* var. *pensylvanica*
1			*Perilla frutescens*
	2		*Phlox divaricata*
1		3	*Phryma leptostachya* var. *leptostachya*
1	2	3	*Podophyllum peltatum*
1	2		*Polygonatum biflorum* var. *commutatum*
	2		*Polemonium reptans* var. *reptans*
		3	*Potentilla simplex* var. *simplex*
1	2	3	*Ranunculus* sp.
	2		*Ranunculus recurvatus*
1			*Rudbeckia hirta*
1			*Silene virginica*
1	2		*Smilacina racemosa*
1	2	3	*Stellaria media*
		3	*Taraxacum officinale*
		3	*Tradescantia ernestiana* f. *ernestiana*
1	2	3	*Trillium pusillum* var. *ozarkanum*
	2		*Trillium viridescens*

		3	*Triodanis perfoliata*
		3	*Triosteum perfoliatum*
	2		*Uvularia grandiflora*
	2		*Veronica hederifolia*
1		3	*Viola triloba*
1	2	3	*Zizia aptera*

VEGETATIVE KEY TO *POLYGONUM* IN MISSOURI

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The following key facilitates the field identification of *Polygonum* species in Missouri. In recent decades, what has been traditionally known as the genus *Polygonum* has been subdivided into several separate genera (Flora of North America Editorial Committee, 2005). However, given the familiarity of the genus *Polygonum* to most nonbotanists and because the taxonomy and nomenclature of the group are beyond the scope of this paper, the broad sense of the genus is here maintained. In order to accommodate the abundance of names associated with the group, a list of synonyms is provided for each species.

Members of the genus *Polygonum* are easily recognized by their fused and sheathing scarious stipules (ocreae), swollen nodes, and alternate, simple, untoothed leaves. Several natural groups are evident within the genus. Section *Polygonum* represents the knotweeds, which are characterized by their procumbent to ascending habit, jointed leaf petioles and few-flowered axillary inflorescences. Section *Persicaria* represents the smartweeds and is characterized by a usually ascending to erect habit, well-developed ocreae, lanceolate leaves, and terminal inflorescences. Section *Echinocaulon* represents the tear-thumbs and is characterized by a sprawling habit, prickly stems, and sagittate or hastate leaves. Section *Tiniara* contains the climbing buckwheats and is characterized by a twining habit and paniculate inflorescences. However, one of its species, *P. cuspidatum*, has stout, non-twining stems. Finally, section *Tovara*, represented in the New World only by *P. virginianum*, is characterized by an erect habit, an elongate, sparse, spicate inflorescence, and beaked styles.

One of the defining characters for section *Polygonum* is the "joint" of the petiole to the stem (Fig. 1). This tends to be difficult to diagnose for those unfamiliar with the character and often requires at least 10× magnification. Basically, the joint appears as

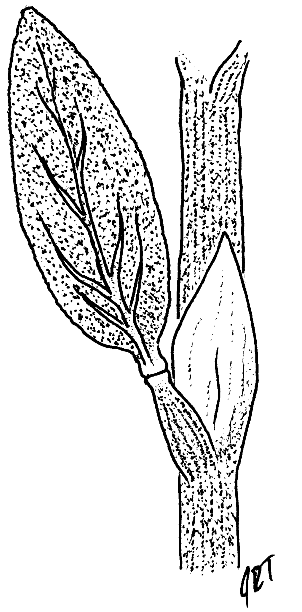

Fig. 1. Node of *Polygonum aviculare* showing the sheathing stipules (ocrea) and the joint near the tip of the petiole.

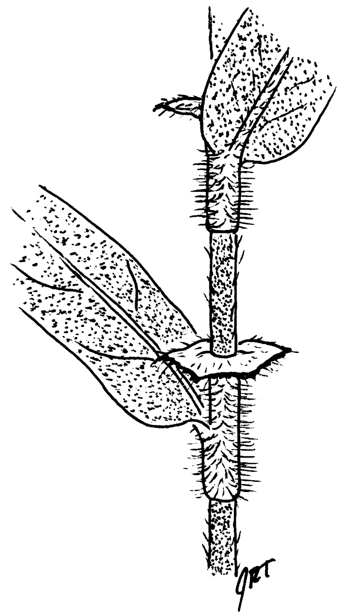

Fig. 2. Two nodes of *Polygonum amphibeum* var. *stipulaceum* showing the sheathing stipular tube (ocrea) with its shelflike apex.

a lateral seam somewhere between the base of the leaf blade and the base of the petiole.

Within section *Persicaria*, characters of the ocreae are often useful for identification. Veins within the ocreae of some species extend beyond the summit as cilia, whereas the veins of others terminate at or before the summit. The ocreae of some species (*P. hydropiper*, *P. punctatum*, and *P. densiflorum*) are beset with glandular punctations. These punctations are best seen by peeling an ocrea away from the stem and looking through it against a lit background. At least 10× magnification is recommended for this procedure and one must be cautious not to mistake the thickened bases of hairs for punctations.

In general, smartweeds are larger, more erect, and occur in wetter habitats than knotweeds. With a few exceptions, both smartweeds and knotweeds are tolerant of disturbance and have little fidelity to high quality natural communities. However, they are a valuable food source for wildlife, especially migrating waterfowl.

1. Plants vine-like; often sprawling over other vegetation
   2. Stems with prickles
      3. Leaves with backward pointing lobes oriented away from the petiole (hastate); rarely encountered. . . . . *P. arifolium*
      3. Leaves with backward pointing lobes oriented toward or parallel to the petiole (sagittate); commonly encountered. . . . . *P. sagittatum*
   2. Stems unarmed
      4. Basal lobes of largest leaves narrowed to a blunt or pointed tip; leaves hastate to sagittate; exotic annual; calyx without winged tissue. . . . . *P. convolvulus*
      4. Basal lobes of largest leaves rounded and not coming to a blunt or pointed tip; leaves more or less cordate; native perennial or annual; calyx with conspicuous winged tissue. . . . . *P. scandens*
1. Plants not vine-like; not typically sprawling over other vegetation
   5. Leaves ovate to broadly ovate and often broadly rounded, truncate or cordate at the base
      6. Leaf bases broadly truncate; plants becoming shrub-like.. . . . . *P. cuspidatum*
      6. Leaf bases narrowly truncate, cordate or rounded; plants herbaceous
         7. Plants growing in water; leaves often floating
            8. Leaves and stems typically glabrous; rarely encountered. . . . . . . *P. amphibium* var. *stipulaceum*
            8. Leaves and stems conspicuously pubescent; commonly encountered . . . . *P. amphibium* var. *emersum*
         7. Plants terrestrial (though often in wet soil); leaves not floating
            9. Stems, petioles and midribs with short, soft, erect hairs; plants with diffuse branching . . . . *P. orientale*
            9. Stems, petioles and midribs with pubescence not as above or glabrous; plants unbranched or with few branches from the main stem
               10. Leaves broadly elliptic to broadly ovate with rounded bases and acute to acuminate

tips; plants of dry to moist soils. . . . *P. virginianum*

10. Leaves lanceolate to oblong with more or less truncate leaf bases and lacking acute to acuminate tips; plants of wet soils
    11. Summits of ocreae oriented perpendicular to the stem and forming a shelf (Fig. 2) .. . . *P. amphibium* var. *stipulaceum*
    11. Ocreae appressed to the stem for their entire length.. . . . . . *P. amphibium* var. *emersum*

5. Leaves elliptic, lanceolate, linear or oblong with rounded, tapering or cuneate bases
   12. Main stem leaves 0.5 – 6 cm long and possessing a noticeable joint along the petiole (Fig. 1) (see paragraph 3 of introduction)
       13. Stems angular; leaf margins with a minute rough texture; plants of acidic soils (granite,sandstone, chert) of glades and rocky prairies. . . . . *P. tenue*
       13. Stems rounded; leaf margins smooth; plants typically of alluvial or ruderal soils, rarely in acidic glades or prairies
       14. Leaves obovate to elliptic and with obtuse or rounded tips; leaves less than three times as long as wide, typically 10–25 mm wide
           15. Leaves elliptic to oval with obtuse tips; leaves sparse, 2.5–6 cm long and 1–3 cm wide, yellow-green; stems not stout in relation to overall stature. . . . . P. erectum
           15. Leaves obovate with rounded tips; leaves relatively dense, 1–3.5 mm long and 0.3–1.5 mm wide, blue-green to silver-green; stems stout in relation to overall stature.. . . . . *P. achoreum*
       14. Leaves linear, narrowly lanceolate, or oblanceolate and with acute or blunt tips; leaves more than 3 times as long as wide, typically less than 10 mm wide
           16. Plants procumbent to weakly ascending; common weed of disturbed soils; leaves more or less blue-green. . . . . *P. aviculare*
           16. Plants erect to strongly ascending; plants of open floodplains and prairies; leaves grass-green . . . . *P. ramossisimum*

12. Main stem leaves greater than 6 cm long and lacking a joint along the petiole
  17. Summits of ocreae oriented perpendicular to the stem and forming a shelf (Fig. 2) . . . . *P. amphibium* var. *stipulaceum*
  17. Summits of ocreae appressed to the stem for their entire length
    18. Veins within ocreae not or barely extending (< 1 mm) beyond the summits of the ocreae (eciliate)
      19. Ocreae with punctations (see paragraph 4 of introduction). . . . . *P. densiflorum*
      19. Ocreae without punctations
        20. Petioles glabrous to glabrate (sometimes marginally ciliate)
          21. Leaves 1–4.8 cm wide; plants with styles and stamens included within the calyx (homostylous); achenes with straight sides; commonly encountered. . . . . . . *P. pensylvanicum*
          21. Leaves 1–2.3 cm wide; some plants with exserted styles and others with stamens exserted (heterostylous); achenes with a hump on one side; rarely encountered .. . . P. *bicorne*
        20. Petioles with appressed pubescence on upper and lower surfaces
          22. Petioles sparsely to densely pubescent with coarse broad-based short hairs; stems and leaf blades rarely conspicuously pubescent; lower leaf surface beset with glandular punctations. . . . . *P. lapathifolium*
          22. Petioles densely pubescent with long, rather coarse hairs; stems and leaf blades usually conspicuously pubescent; lower leaf surface lacking glandular punctations . . . . *P. amphibium* var. *emersum*
    18. Veins within the ocreae extending beyond the summits of the ocreae as long, conspicuous cilia greater than 1 mm long

23. Hairs on body of ocreae and petioles very coarse and dense, spreading or ascending. . . . . *Polygonum setaceum*
23. If present, hairs on body of ocreae thin, sparse and appressed to the body of the ocreae (the hairs of *P. amphibium* var. *emersum* can be coarse and dense, but are appressed to the petiole rather than ascending or spreading)
    24. Ocreae with glandular punctations (see paragraph 4 of introduction)
        25. Stems typically reddish; leaves lance-elliptic; ocreae loose and often widening toward the summit (gaping); inflorescence often sparse but usually with overlapping flowers; achenes dull due a minutely roughened texture. *P. hydropiper*
        25. Stems rarely or barely reddish; leaves lanceolate to narrowly lanceolate; ocreae typically tight and appressed to the stem; inflorescence very sparse and rarely with overlapping flowers; achenes shiny due to a very smooth texture. . . . . *P. punctatum*
    24. Ocreae without punctations
        26. Bristles of ocreae as long, nearly as long, or longer than the body of the ocreae . . . . *P. cespitosum* var. *longisetum*
        26. Bristles of ocreae shorter than the body of the ocreae
            27. Plants conspicuously pubescent with long, coarse, dense hairs; leaves often broadly rounded to subcordate at base (especially the upper leaves) . . . . *P. amphibium* var. *emersum*
            27. Plants glabrous to more or less densely pubescent with short, broad-based hairs (especially on petioles and midribs of leaves); leaves tapering or slightly rounded at base
                28. Ocreae, petioles and midrib of leaves glabrous to finely pubescent with weak, thin, often crooked hairs; plants annual. . . . . *P. persicaria*
                28. Ocreae, petioles and midrib of leaves with distinctly broad-based, coarse, light colored hairs of variable density; plants perennial . . . . *P. hydropiperoides*

Polygonum achoreum S.F. Blake (*Polygonum erectum* L. subsp. *achoreum* Á. Löve & D. Löve).—Given its obovate leaf shape and rounded blade tips, *P. achoreum* is one of the most distinct species of small knotweeds in Missouri. It has an erect habit when it is young but becomes prostrate or decumbent with age. *Polygonum achoreum* is a homophyllus plant (with leaves of the flowering branches similar in size to those of the main stem) with stout stems. Although variable, it tends to have blue-green leaves. The achenes are beaked. Although native to North America, this species is apparently exotic in Missouri. It is an uncommon annual of disturbed, often nutrient rich, soils.

Polygonum amphibium L. var. ***emersum*** Michx. (*Persicaria amphibia* (L.) Gray var. *emersa* (Michx.) Hickman; *Persicaria coccineum* (Muhl. ex. Willd.) Greene; *Polygonum coccineum* Muhl. ex. Willd.).—Commonly referred to as *Polygonum coccineum*, this variety and the next have undergone a fluctuating taxonomy. The taxonomic confusion is thought to stem from habitat induced morphologies. It is the author's opinion that enough distinction occurs within the state to at least warrant varietal recognition. Those interested in the debate should see Peattie (1930) and Swink and Wilhelm (1994). Due to its hypervariable morphology, this taxon can be difficult to place in the key, however it is readily identified in the field. Field characters for identification include its stocky stature, colonal growth, wide leaves and appressed, hairy ocreae. In the dormant season, dry and weathered specimens can be identified by their orange-brown, "tobacco" color. The typical variety is European. *Polygonum amphibium* var. *emersum* often grows in colonies and is found in saturated to moist soils of marshes, floodplains and other areas of natural integrity.

Polygonum amphibium L. var. ***stipulaceum*** N. Coleman (*Persicaria amphibia* (L.) Gray var. *stipulacea* (Coleman) Hara).—The morphology of this taxa varies greatly with water supply. When inundated, the plants are glabrous, have longer petioles, floating leaves (resembling a *Potamogeton*) and appressed ocreae. However, when the plants are terrestrial they have varying degrees of pubescence and the ocreae develop a shelf around the summit (Fig. 2). Prior to 1998, this taxon had not been seen in

Missouri since the 1890's (Smith, 1998). Currently it is only known from five widely scattered counties. Throughout its range, it is typically found in wetter conditions than most other species of *Polygonum*.

Polygonum arifolium L. (*Persicaria arifolia* (L.) Haraldson).—This is one of two species of *Polygonum* in Missouri with prickly stems. It is readily distinguished from *P. sagittatum* by the characters listed in the key. In Missouri, *Polygonum arifolium* is only known from Butler and Stoddard Counties.

Polygonum aviculare L.—In Missouri, this complex consists of four subspecies: subsp. *aviculare*; subsp. *buxiforme* (Small) Costea & Tardiff (*P. buxiforme* Small), subsp. *depressum* (Meisn.) Arcang. (*P. arenastrum* Boreau); and subsp. *neglectum* (Besser) Arcang. (*P. neglectum* Besser); each of which have also been treated at the species level. For a discussion of identification and taxonomy of this group the reader is directed to the treatments of Yatskievych and Brant (1994) and Costea et al. (in Flora of North America Editorial Committee, 2005). The *P. aviculare* complex represents the smallest members of the genus found in Missouri, and is characterized by a more or less prostate habit and affinity to disturbed, compacted, or saline soils. Only *P. aviculare* subsp. *buxiforme* is considered native to the state.

Polygonum bicorne Raf. (*Persicaria bicornis* (Raf.) Nieuwland, *Persicaria longistyla* (Small) Small; *Polygonum longistylum* Small).—This species strongly resembles *P. pensylvanicum* (see comments under that species) and flowering or fruiting material is often necessary to validate an identification. However, *P. bicorne* is rarely encountered in the state and typically has narrower leaves than *P. pensylvanicum*. It is found in a variety of wet to moist habitats.

Polygonum cespitosum Blume var. ***longisetum*** (Bruijn) Stewart (*Persicaria cespitosa* (Blume) Nakai var. *longiseta* (Bruijn) Reed, *Persicaria longiseta* (Bruijn) Kitag., *Polygonum longisetum* Bruijn).—At the time of Steyermark's (1963) *Flora of Missouri*, this Asian smartweed was known only from St. Louis County. Since that time, it has become one of the more common species of

Polygonum in the state. It is readily identified by its rhombic-lanceolate leaves, deep pink flowers and the long cilia at the summits of the ocreae. It is commonly found in moist lawns, disturbed woods, stream banks, gravel bars, and floodplains.

Polygonum convolvulus L. (*Fallopia convolvulus* (L.) Á. Löve).—This European species represents one of only two species of twining unarmed knotweeds in the state. Although most specimens are readily identifiable by the characters listed in the key, one may occasionally encounter a specimen with leaves too intermediate for comfort. In such instances, it is best to rely on floral characters. This matter is further complicated by reports of the European *P. dumetorum* being present in Missouri (Flora of North America Editorial Committee, 2005). Because the debate regarding the taxonomic status of *P. dumetorum* is currently unsettled, one should be suspect of specimens that key to *P. convolvulus* and that have noticeable winged tissue running the length of the tepals. This species is a rank weed of waste ground, grain elevators, field edges and railroads.

Polygonum cuspidatum Siebold & Zucc. (*Fallopia japonica* (Houtt.) Ronse Decr., *Reynoutria japonica* Houtt.).—This is a notoriously invasive species that spreads rapidly and is difficult to eradicate. It seems the farther east one travels in North America, the more pervasive this species has become. It is especially abundant in the moist valleys and along streams and rivers in the Appalachian and Allegheny Mountains. It is easily identified by its large spade-shaped leaves with truncate bases and its shrub-like growth form often taller than a person. Seldom encountered as a single stem, *P. cuspidatum* forms large colonies that rapidly displace native vegetation. In Missouri, it inhabits roadsides, floodplains, waste ground, railroad embankments, and open woods. It should be eradicated wherever it is encountered. One common name is Mexican bamboo, although it is neither; another more appropriate common name is Japanese knotweed.

Polygonum densiflorum Meissn. (*Persicaria densiflora* (Meisn.) Moldenke).—This smartweed is easily recognized by its large leaves, punctate ocreae, and tendency to root at the nodes. *Polygonum densiflorum* is currently classified as “State Historic” and has not been seen in Missouri since 1973. The site of the last known occurrence was destroyed by the impoundment of Mark Twain Lake (Smith, 2004). It is maintained here in hope that, if encountered, it will not go undetected. It once inhabited wet woods and swamps in the southeastern part of the state. Some botanists believe that this species and *P. glabrum* Willd. (*Persicaria glabra* (Willd.) M. Gómez) represent the same taxon; in that case this older, epithet must be used for the taxon.

Polygonum erectum L.—This is an erect to ascending annual with elliptic leaves. *Polygonun erectum* is commonly mistaken for *P. aviculare* but differs in being significantly larger, more upright, and having wider leaves in relation to width. Although considered native, *P. erectum* is typically found in dry disturbed soils of farm lots and fields, as well as in woodlands and shaded floodplains.

Polygonum hydropiper L. (*Persicaria hydropiper* (L.) Spach).—This species is commonly confused with *P. punctatum*, due to the subtlety of characters used to distinguish the two. Although the most reliable characters are the degree of overlap of the flowers and the texture of the achenes, stem color and leaf shape work surprisingly well for field diagnosis. *Polygonum hydropiper* often produces cleistogomous flowers within the ocreae. This species is native to both Europe and North America, but there apparently is no way to distinguish native and introduced populations morphologically. It is found throughout the state in a variety of wet, often disturbed, habitats.

Polygonum hydropiperoides Michx. (*Persicaria hydropiperoides* (Michx.) Small; *Persicaria opelousana* (Riddell ex Small) Small, *Polygonum opelousanum* Riddell ex Small).—This is a hypervariable species throughout its range. Specimens with plate-like glands within the inflorescence have been referred to as *P. opelousanum*, but too much intergradation exists for even varietal recognition (Flora of North America Editorial Committee, 2005). *Polygonum setaceum* (formerly *P. hydropiperoides* var. *setaceum*) may occasionally key here but differs in having the hairs of the ocreae fused to the ocreae for less than a third of their length, whereas the ocrea hairs of *P. hydropiperoides* are fused for more than one third their length. A characteristic wetland species found growing throughout the state along the borders of swamps, springs, ponds, and other habitats with saturated soils, typically in unshaded areas.

Polygonum lapathifolium L. (*Persicaria lapathifolia* (L.) Gray).—This is one of Missouri's largest native smartweeds and is readily identified by its eciliate ocreae, punctations on the lower leaf surface, and sparse, short, broad-based, rough hairs on the petioles and midribs of leaves. When viewed with 10× magnification, these hairs appear short, whitened, and triangular. The secondary veins of this species give the upper leaf surfaces a unique texture that can be seen from some distance. *Polygonum lapathifolium* occurs in unshaded habitats throughout the state, but sparingly in the Ozarks. It occurs in wet, often disturbed sites such as mud flats and along the margins of artificial ponds. It also is common in more upland disturbed sites, such as waste ground, spoil banks and along the margins of crop fields.

Polygonum orientale L. (*Persicaria orientalis* (L.) Spach).—This Asian species is easily identified by its large stature, branching habit and pilose to hirsute stems, petioles, midribs and inflorescences. *Polygonum orientale* occasionally escapes cultivation and is uncommonly encountered. It is typically found in dry to moist soils of vacant gardens and disturbed sites.

Polygonum pensylvanicum L. (*Persicaria pensylvanica* (L.) M. Gómez).—With its rosy-pink flowers (rarely white) arranged in a dense cylindric inflorescence, this is one of the most attractive smartweeds in Missouri. It often has gland-tipped hairs on the peduncle just below the inflorescence. Specimens lacking gland-tipped hairs have been referred to as *P. pensylvanicum* var. *eglanudulosum* Myers. *Polygonum pensylvanicum* strongly resembles *P. bicorne*, however the leaves of *P. bicorne* tend to be narrower than those of *P. pensylvanicum*. Furthermore, *P. bicorne* is rarely encountered in the state, whereas *P. pensylvanicum* is one of our most common smartweeds. It is found throughout the state in a variety of wet to moist habitats.

Polygonum persicaria L. (*Persicaria maculosa* Gray).—This European weed often has a dark spot on the center of the upper leaf surfaces from which the common name lady's thumb is derived. *Polygonum persicaria* superficially resembles *P. cespitosum* but has shorter cilia on the summits of the ocreae. Its inflorescence can resemble that of *P. pensylvanicum* from a distance, but closer inspection regarding the presence of ciliate ocreae will easily rule out the latter. *Polygonum persicaria* is widespread in our range in a variety of open to shaded disturbed habitats.

Polygonum punctatum Elliot (*Persicaria punctata* (Elliott) Small).—The epithet *punctatum* refers to the punctate glands that cover the calyces. Punctations in this species, as well as in *P. hydropiper* and *P. densiflorum*, can also be found on the ocreae. *Polygonum punctatum* closely resembles *P. hydropiper* and the two are often confused (see notes under *P. hydropiper*). Voss (1985) reported that in Michigan, *P. punctatum* demonstrates more of an affinity to shady habitats than do other species. This seems to hold true for Missouri plants as well. Although *P. punctatum* is a more conservative species than *P. hydropiper*, both can be found in a variety of wet habitats including areas of disturbance. *Polygonum punctatum* is the classical smartweed of shaded, seasonally wet depressions.

Polygonum ramosissimum Michx.—This knotweed is readily identified by its erect to ascending habit, linear to lance-linear leaves with acute tips and a yellow-green coloration. Most specimens are conspicuously heterophyllous (having main stem leaves significantly larger than those of the fertile branches). Although native, *P. ramosissimum* is scattered throughout the state in a variety of disturbed habitats, often occurring in alluvial soils.

Polygonum sagittatum L. (*Persicaria sagittata* (L.) H. Gross).—This species is one of two tear-thumbs in Missouri that possess prickles on the stem. Unlike that of *P. arifolium*, the range of *P. sagittatum* includes the entire state. It can form extensive, sprawling colonies and often clambers over other vegetation. It is found in a variety of native wetland habitats of varying quality.

Polygonum scandens L. (*Fallopia scandens* (L.) Holub).—Superficially resembling *P. convolvulus*, but typically more robust, this species is one of two twining species of knotweeds in Missouri. As mentioned under *P. convolvulus*, there are reports of a third species, *P. dumetorum*, which some authors lump with *P. scandens*. However, based on leaf characters, *P. dumetorum* is more likely to be keyed to *P. convolvulus* than *P. scandens*. Both *P. scandens* and *P. dumetorum* differ from *P. convolvulus* in having conspicuously winged keels along the length of their tepals. For details of the floral distinctions of these taxa the reader is directed to the treatment of Hinds and Freeman (in Flora of North America Editorial Committee, 2005). *Polygonum scandens* is found in wooded habitats throughout the state, including forest and field edges, tree gaps in disturbed woods, and thickets, where it commonly sprawls over other vegetation.

Polygonum setaceum (Baldwin) Small (*Polygonum hydropiperoides* Michx. var. *setaceum* (Baldwin) Gleason).—With long, bristly, spreading hairs, this is the most conspicuously pubescent smartweed in Missouri. In the key, the user may be tempted to place specimens of *P. amphibium* var. *emersum* here due to confusion in pubescence characters. However, even when the hairs on the ocreae of *P. setaceum* are ascending, they are more coarse and dense than those of *P. amphibium* var. *emersum*. *Polygonum. setaceum* is mostly limited to the southern half of the state and can be found in a variety of habitats including swamps, ponds, stream edges, and springs (Steyermark, 1963).

Polygonum tenue Michx.—This species is easily recognized by its strict appearance, erect habit, angled stems, narrow leaves, blue-green cast, and fidelity to dry acidic habitats. This handsome little plant is the most conservative species of knotweed in our flora. It is found nearly throughout Missouri but is apparently is absent from the northeastern counties.

Polygonum virginianum L. (*Persicaria virginiana* (L.) Gaertn., *Tovara viginiana* (L.) Raf.)—This is an erect species with broadly ovate leaves, a narrow, sparsely-flowered, spicate inflorescence, and beaked styles. When in fruit, it is entertaining to strip the inflorescence from the base up and watch the fruits spring into the air. This phenomenon is the source of the common name jumpseed. *Polygonum virginianum* is common in dry to moist woods throughout Missouri.

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USING THE NATIONAL WETLAND INVENTORY AS A TOOL TO LOCATE FENS AND OTHER RARE MISSOURI WETLAND NATURAL COMMUNITIES

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Fens are rare, botanically rich wetland communities scattered throughout the state. Of the170 sites listed in the Missouri Natural Heritage Database, nearly 80% are Ozark fens (Nelson, 2005). Other recognized fens include prairie fens, forested fens, and glacial fens. Total acreage encompassed by these wetland natural communities is about 411 acres (Nelson 2005). Most fens are small and only average about 2.5 acres per site (Nelson, 2005). Ozark fens, prairie fens, and forested fens are given a S2 rank (imperiled in the state due to rarity or because of some factor(s) making it very vulnerable to extirpation) by the Missouri Natural Heritage Program (2006), but glacial fens are ranked as S1 (critically imperiled in the state due to extreme rarity or because of some factor(s) making it especially vulnerable to extirpation). Numerous species of plants tracked by the Missouri Natural Heritage Program (2006) inhabit fens (see Nelson [2005] for a list of species).

In 1999, Linden Trial discovered the federally listed endangered Hine's emerald dragonfly (*Somatochlora hineana* Williamson) at Grasshopper Hollow in Reynolds County, Missouri. Since then, Missouri fens have received significant attention from odonatologists searching for this dragonfly. Subsequent surveys conducted for the Hine's emerald between 2001 and 2005 led to the discovery of 25 additional sites scattered across the Missouri Ozarks in 10 different counties (see summary through 2004 by McKenzie and Vogt [2005]). During roughly the same time period, surveys for fens by multiple naturalists led to the discovery of sites that had not been previously inventoried. Botanical explorations at these fens yielded several species of state-tracked flowering plants, mosses, and liverworts.

The identification of potential fen habitat for Hine's emerald dragonfly has involved various evaluations since 2001. Initially, potential sites were identified by searching the Missouri Natural Heritage Database for suitable fens. Potential survey sites were chosen based primarily upon whether or not they were dominated by herbaceous vegetation (vs. woody), ecological and hydrological integrity, and size. Additional sites were suggested by knowledgeable individuals, frequently field biologists with government agencies. At the end of the 2004 survey season, many researchers were under the impression that all known high-quality fens had been searched and that it was unlikely that additional populations of Hine's emerald dragonfly would be discovered.

During a review of a highway project in Wayne County, Missouri, in the summer of 2004, my Field Supervisor, Charlie Scott, asked me to exam our agency's National Wetland Inventory (NWI) maps, to determine if any wetlands occurred within the project corridor outlined for the highway, and to assess if there was any potential habitat for the Hine's Emerald. Such maps have been drafted for many (but not all) states in the United States. Completed NWIs are the same size as 7.5 minute topographic maps and match up with these when superimposed on top of one another on a light table. Various wetland types following designations outlined in Cowardin et al. (1979) have been identified by using aerial photogrammetry data that were then transferred onto topographic maps. Wetlands are then frequently visible that may not be evident on the topographic maps alone. However, ground-truthing is necessary to confirm the predicted presence of wetlands as outlined using this method.

In examining the NWI maps for the above-mentioned highway project, I noticed that there were multiple wetland designations within the proposed highway corridor. To determine if there was potential fen habitat for Hine's emerald dragonfly, I compared the project area NWI feature codes with NWI feature codes from known sites for the dragonfly in Missouri and discovered that all but two of the fens known to harbor this insect have one wetland feature designation in common on the NWI maps: PEMB. PEMB is identified as a palustrine wetland with emergent vegetation and saturated soils (following Cowardin et al.'s [1979] designations). Such a designation is an excellent descriptor for Missouri fens. Although there were few wetlands coded as PEMB within the highway project corridor I reviewed, I decided to further investigate the possibility of using this descriptor as a possible means of identifying unrecorded fens in the 10 counties where dragonfly populations had been documented.

To assist in the analysis, I solicited assistance from Bob Gillespie, Regional Natural History Biologist with the Missouri Department of Conservation, who had access to Geographic Information Systems data at his office and is also the agency's Recovery Coordinator for Hine's emerald dragonfly. Our analysis led to the discovery of numerous fens that either were not listed in the Missouri Natural Heritage Database or were unknown to ecologists and naturalists within the state. These included fens that were not identified in Orzell's (1983a, b) assessment of fens in the Missouri Ozarks or during various county Natural Features Inventories completed by the Department for the ten counties from which the rare dragonfly has been documented.

National Wetland Inventory maps are available for use, copying, etc. by visiting the U.S. Fish and Wildlife Service's National Wetlands Inventory site at: http://www.fws.gov/nwi/downloads.htm. There are step-by-step directions on getting access to NWI maps and how visitors to the website can use the data.

In addition to fens, examination of NWI maps can lead to the identification of other Missouri wetlands that may not be evident on regular topographic maps, such as marshes and sinkhole ponds. Depending on the age and quality of data used, NWIs may depict changes in wetland size, duration, and type (e.g., conversion of a fen to a pond, drying of a sinkhole pond due to drought, etc.). Once rare wetland natural communities have been identified and landowner permission has been granted for sites on private property, site visits may yield the discovery of rare plants and animals tracked by the Missouri Natural Heritage Program. Using NWI data in such a manner has led to the documentation of multiple state-tracked plant species.

Using NWIs to identify rare wetland natural communities is not without its drawbacks. Limitations include: 1) aerial photographs used in NWI development are in some cases too old to accurately reflex the current status of various wetlands; 2) ground-truthing of sites can be labor-intensive and occasionally impossible to conduct on some privately owned properties; 3) NWIs can fail to identify even high-quality wetlands (e.g., Barton Fen in

Reynolds County); 4) aerial photographs used are not detailed enough to locate very small wetland natural communities such as acid seeps.

Despite the limitations outlined above, however, I believe that analysis of National Wetland Inventory data is a tool that has not been used to its fullest capacity and that it will continue to have expanded applicability in the search for rare plant species in Missouri.

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BOOK REVIEW

Nelson, Paul W. 2005. The Terrestrial Natural Communities of Missouri, revised edition. Missouri Natural Areas Committee, Jefferson City, MO. ix, 550 pp. $29.95. (no ISBN Number). Hardbound.

First published in 1985, Nelson's *The Terrestrial Natural Communities of Missouri* has been an important tool for scientists, naturalists, and land managers for many years. Readers will find the 2005 revision considerably different from the original in the text, layout, and depth.

The most readily apparent change in the revision is its appearance. The new version is hardbound and over 500 pages in length. The nearly 300 photographs, digital images, maps, and charts are in color. The color in the new revision is both inviting and instructive, providing visual representation of some of the best examples of high quality natural communities in the state. Indeed, the quality of the photos, which incidentally were provided by some of the best photographers in the state, including Nelson, puts this book on par with some higher priced "natural history" coffee table books. The striking appearance alone is enough to attract the interest of the casual observer.

One downside of the size and shape of the new revision is that its heft discourages its use as a field guide. Those who may have dutifully carried the old version in their back packs may now find the revised Nelson better used as a desk reference than field guide.

Nelson has added several chapters to the revision dealing in-depth with Missouri biogeography, ecological management, and conservation goals and planning. The detail of these chapters provides a solid background for the amateur naturalist and nature enthusiast in Missouri and will serve as a reference for scientists and land managers who work in the area. History buffs will enjoy Nelson's sections within the biogeography chapter linking historical human occupancy of Missouri with the composition, structure, and function of many of the natural communities he describes. The chapter on ecological management is informative, though the majority of the chapter focuses on fire, whereas mechanical and chemical tools such as timber harvest and herbicide are not discussed. Nelson's chapter on conservation goals and planning, in particular, challenges scientists and land managers by pointing out real life threats to natural communities, illustrated with Landsat imagery and data comparing Missouri to other states.

The majority of the revision, like the original, deals with the descriptions of the natural communities themselves. As in the original version the broad categories include forest, savanna, prairie, glade, cliff/talus, stream edge, wetland and cave. However, Nelson and his committee have added a new broad category of Woodland. The group of Woodland communities, of which there are 18, replace some of the communities that had previously been described under Forests. For example, dry-chert forest, dry-mesic chert forest, dry sandstone forest were all converted to woodland community types. The Woodland grouping, as described by Nelson, better depicts the more open overstory and lush ground flora of these communities. In addition, the role of fire is crucial in woodlands. Although some biologists had used Savanna to categorize these types of communities in the past, Nelson makes the distinction that savannas have few trees and mostly grass and are associated with prairies whereas woodlands can have a slightly more developed overstory and are associated with forests. Nelson's use of this terminology is in agreement with conventions used by other community ecologists and scientists in the Midwest, where similar terminology has been in use for the past few years.

Nelson has also changed his characterization of cave natural communities in the revision. In the original version of the book there were five types of cave natural communities based primarily on the relationship of water flow to the cave entrance. These groupings have been reduced to aquatic and terrestrial types based on presence or absence of water, and further divided into subtypes, which can overlap. This is a major step forward in the characterization of cave communities in Missouri. Indeed, the old cave classification made little sense because its characterization was based primarily on the cave entrance. The new classification does a much better job of encapsulating the cave communities that actually exist under the landscape, not just at the cave entrance.

Noteworthy additions within the chapters dealing with the terrestrial natural community descriptions include associated natural communities, status, threats, and management considerations. Sections within the natural community descriptions that deal with vegetation, physical characteristics, natural processes, dominant plants, and characteristic plants have been fully updated and refined using the latest inventory information, geographic information technology, satellite images, and spatial data for the state. Also worth mentioning, although Nelson does focus heavily on indicator plant species, he also spends significant text discussing faunal components of natural communities. For animal community ecologists and naturalists alike, this is a welcomed break from tradition.

Nelson's book gives a comprehensive view of the natural communities in Missouri as well as the forces that shape them and the challenges to managing them. When I heard that a revision was underway, it was hard for me to imagine how the original Nelson could be improved. After all, as a young biologist I carried the 1987 edition into the field until it fell apart—then I laminated it and put it in a binder so I could continue to take it into the field. I might not lug the revision in my backpack like I did with the original, but its importance cannot be understated. Nelson has taken a wonderful piece of work and improved upon it by using the latest technology and information, insights and information from experts, beautiful maps and photographs, and a careful attention to detail that few others could muster. The revision has already taken a place within arm's reach at my desk.

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