CHAPTER ONE:
THE BRODHEAD WATERSHED AND INVASIVE PLANTS

A. Statement of Project and Goals

The Brodhead Watershed Association (BWA) is a non-profit volunteer organization whose primary mission is to protect the environment and water resources within the Brodhead watershed and its smaller neighbor, the Cherry Creek watershed (for brevity, these will be called "the Brodhead watershed" throughout). [1]

In 2002, the BWA published The *Brodhead Watershed Conservation Plan*.[2] This plan identified invasive species as a "serious threat" to the watershed, for "second to habitat loss from development, invasive plants are the next major factor contributing to the decline of native plants in the watershed."[3] At that time, fourteen invasive plant species were considered "serious threats" to the region. In the intervening years, not only has the population of most of these species grown dramatically, several more species have been introduced. The Brodhead Watershed Association (BWA) therefore set a "very important" goal to "implement programs to control/manage invasive… species" in order to "promote biodiversity and to maintain, protect, and enhance natural systems" in the region.[4]

Among the ways that the BWA strives to achieve its goal and mission, is by promoting clarity in popular education about invasive plant species.[5] This report responds to those educational goals by including information that we believe can not only serve as a brief primer on invasive plant species and the damage they can cause, but also offers a general description of possible management strategies**.** This feature of the report is especially important since environmental organizations and scientists often use different and even conflicting definitions for relevant terms. In addition, this report will summarize the results of the BWA's project mapping the location and density of invasive plant species in the region, Phase I of the ISMP, supported through grant # BRC-TAG-RCI-13.3-506 from the PA DCNR.

Note: Citations for all footnotes appear alphabetically by author in the reference list for this plan, beginning on page 57 of this report.

[1] For more on the Brodhead Watershed Association, visit its website at http://www.brodheadwatershed.org.

[2] Available at http://www.brodheadwatershed.org/conservationplan.html, approved by the Department of Conservation and Natural Resources http://www.pabulletin.com/secure/data/vol32/32-33/1428.html.

[3] Brodhead Watershed Conservation Plan, 131.

[4] Brodhead Watershed Conservation Plan, 29.

[5] For more on the Brodhead Watershed region, see the Brodhead Watershed Conservation Plan, available at http://www.brodheadwatershed.org/conservationplan.html

B. Description of the Brodhead Watershed

Covering about 300 square miles, this watershed includes most of Monroe County and part of Pike County in Northeastern Pennsylvania. According to census data for 2009, the region is now home to more than 160,000 people.[6] The most densely populated and commercially developed region is in the Lower Brodhead subwatershed, one of seven distinct subwatersheds, all shown below on Figure 1.

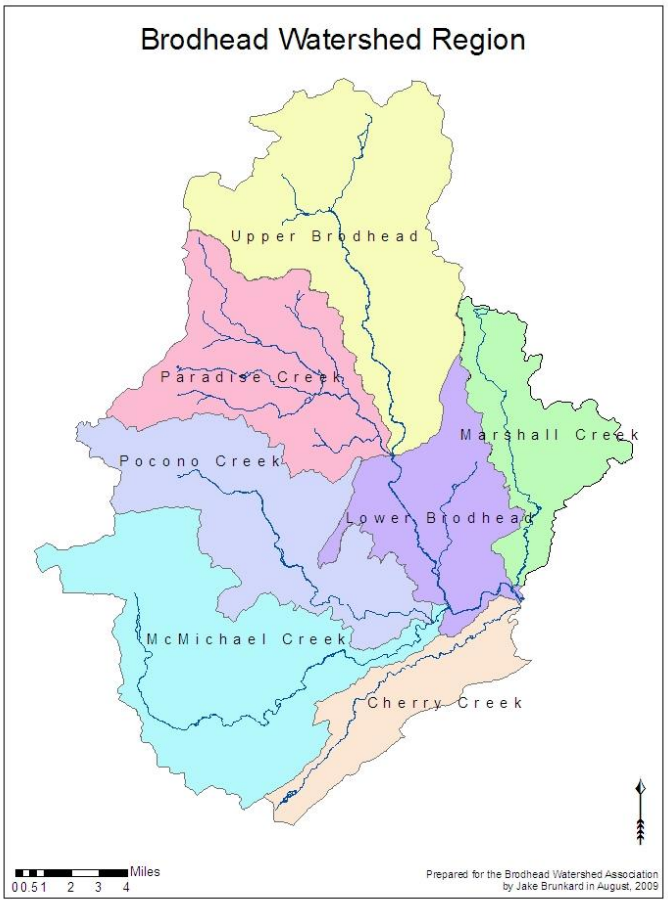

Figure 1. Map of the Brodhead Watershed of Monroe and Pike counties in Northeastern Pennsylvania. Each subwatershed is labeled by its own color. Invasive plant populations were surveyed along the major tributaries of each subwatershed, shown on the map as blue lines.

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[6] United States Census Bureau, http://quickfacts.census.gov/qfd/states/42/42089.html.

Spread over 18 different municipalities (See, Figure 2 below), the region remains heavily forested, with a wide variety of ecosystems, including deciduous hardwood forests, hemlock forests, and pitch pine barrens, as well as boreal bogs and other wetlands.

Portions of the watershed experienced three major floods in 2004-2006, intensifying regional concern for riverside ecosystems since floods and the resulting stream bank erosion and deposition have been implicated in the spread of invasive plants.

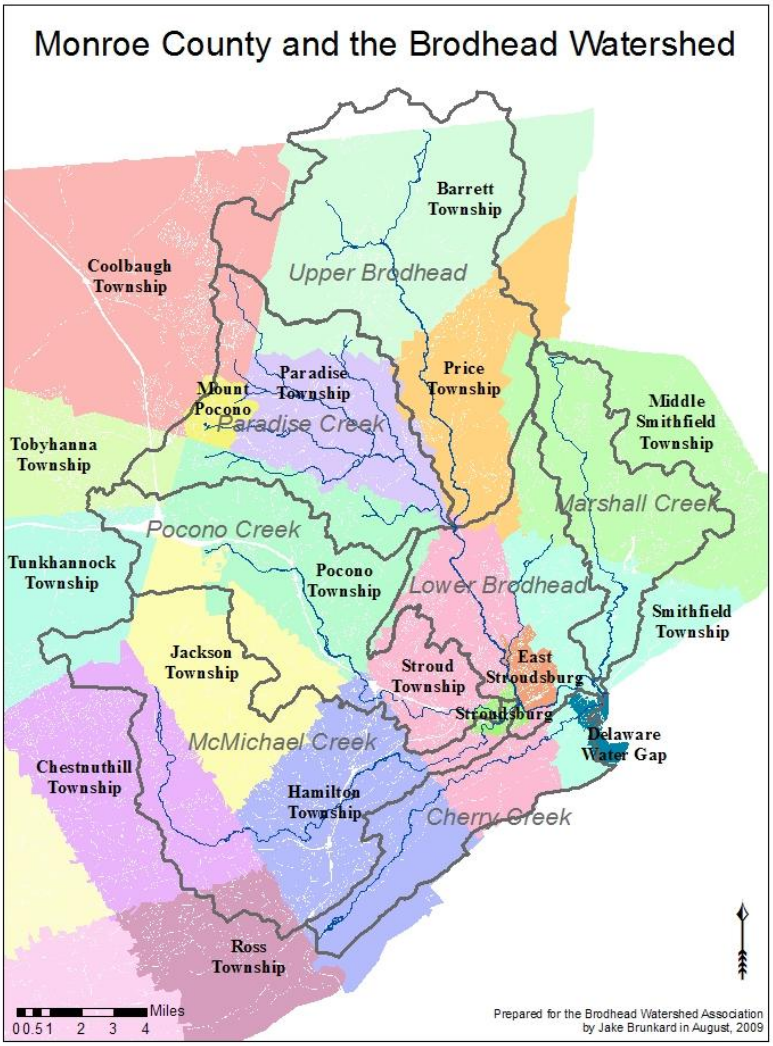

Figure 2. The Brodhead Watershed (grey outlines) covers most of the townships and boroughs of Monroe County, as shown here. Each municipality is indicated by its own color.

C. Reasons for Concern - Invasive Plant Species

C1. What are invasive plant species?

Various terms are used to describe what we will call "invasive plant species," with overlapping and indistinct meanings: "exotic plants," "alien plants," "exotic invasive plants," "non-native plants," "introduced plants," and simply "invasive plants."

Many of these terms are intended to emphasize the *recent anthropogenic (human influenced) introduction* of invasive plant species. They are sometimes used to contrast with "native invasive plants" or "local invasive plants." Indeed, some plant species of neighboring regions will enter new ecosystems and rapidly displace existing plant species, without any direct human involvement; one common local example is the hay-scented fern (*Dennstaedtia punctilobula*), native to North America, but not historically found in abundance in the Brodhead Watershed.

Figure 3. Hay-scented Fern

These "native invasives" are not of primary concern to environmental organizations in the eastern United States, including the BWA[7]

For the purposes of this report we consider invasive plant species to be**:**

> *any plant species introduced to the region by humans in recent decades that are actively spreading and replacing local plant communities.*

C2. Ecology: Invasive Plants and Biodiversity in Riparian Areas

Figure 4. The classic case: Invasives overwhelm the natives

Invasive plant species are typically able to invade an ecosystem precisely because they are able to successfully compete with native species by gathering better access to light, space, nutrients, and water. Native plant species that previously thrived may be displaced or even made extinct under this intense competitive pressure for resources imposed by invasive plants.

The sections that follow will outline some of the specific threats to biodiversity posed by invasive plant species in the Brodhead Watershed region.

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[7] Putting aside any environmentalist or scientific debate about the relative importance of "native" and "alien invasives," the BWA's decision here is largely strategic: our region's environment is more adversely affected by "alien invasives," an assertion supported by local naturalists and our survey teams, so these are the BWA's primary concern.

C2a. Impact on Threatened, Endangered, and Rare Plants and Animals

The Pennsylvania Natural Heritage Program has identified well over 200 plant and animal species of concern in the Brodhead Watershed.[8] Invasive plant species are believed to be the largest single threat to endangered and threatened species, besides direct habitat destruction caused by human construction projects.[9] Beyond direct competition for space and resources with rare plant species, invasive plants can also replace the native food sources and habitats of rare animal species. Recent studies have demonstrated that nesting birds, including rare species, may be at greater risk of predation when building nests in invasive shrubs, including multiflora rose and invasive honeysuckles.[10]

Recommendation: Efforts to conserve rare, threatened, and endangered species in the Brodhead Watershed must coordinate with efforts to limit the spread of invasive plant species.

C2b. Impact on Cooperative Invasive Species and Cascade Effects

Recently, several studies have emphasized the potential for certain invasive plant species to modify their environment, leading to *cascade effects* in the invaded ecosystem.[11] We consider a cascade effect to be "a series of secondary extinctions triggered by the primary extinction of a key species in an ecosystem."[12] According to Olsen, et al (1991):

> *Such secondary extinctions are likely to occur when the threatened species are: 1) dependent on a few specific food sources, 2) dependent on the key species in some way, or 3) forced to coexist with an invasive species that is introduced to the ecosystem. Species introductions to a foreign ecosystem can often devastate entire communities, and even entire ecosystems. These exotic species monopolize the ecosystem's resources, and since they have no natural predators to decrease their growth, they are able to increase indefinitely.*

For example, a series of studies in the deciduous hardwood forests of New Jersey found that Japanese barberry and Japanese stiltgrass may promote the spread of exotic invasive earthworm species and drastically change chemical properties of

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[8] For a complete list, see http://www.naturalheritage.state.pa.us/.

[9] Gurevitch and Padilla, 2004

[10] Rodewald et al 2010

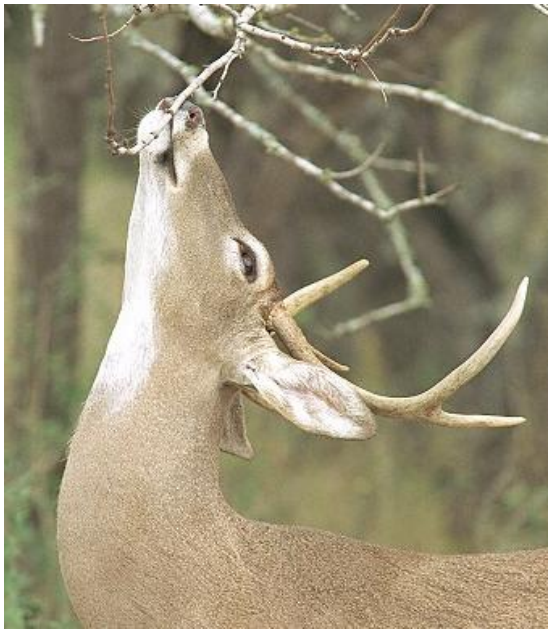
[11] For a review, see K. Cuddington and A. Hastings, "Invasive engineers," *Ecological Modelling* 178 no.3-4 (2004): 335-47.

[12] Olsen, T.M. et al., 1991

the soil (such as nutrient resource availability and acidity).[13] Once they invade a native ecosystem, then, particular emphasis should be placed on quickly removing these invasive species that change soil properties and are associated with invasive animal species.

Recommendation: Long-term management strategies should recognize that native plant populations may not be able to return and thrive until several years after removal of these kinds of invasive plants.

C2c. Relationship Between Deer Grazing and Invasive Plants



Anecdotal evidence has previously suggested that deer avoid grazing on the thorny invasive plant species, especially Japanese barberry and multiflora rose. A recent regional study conducted by scientists at East Stroudsburg University confirmed that native tree seedlings are significantly more likely to survive infancy if protected from *both* deer (by fenced enclosures, for example) and competition from invasive plants (by mechanical removal).

Figures 5 and 5a: Why young plants need fenced protection from white-tailed deer.

Recommendation: Neighborhood efforts to remove invasive plant species should therefore consider using tall fencing to protect native replacement plants after invasive species have been removed to prevent grazing by deer that could allow the return of invasive plants.

C3. Environmental Chemistry: Vibrant Riparian Ecosystems and Stream Quality

Riparian forest buffers, which are vibrant, diverse populations of trees, shrubs, and herbaceous plants that grow along streambanks, serve an essential function in maintaining high stream quality in the Brodhead Watershed. These buffers help to

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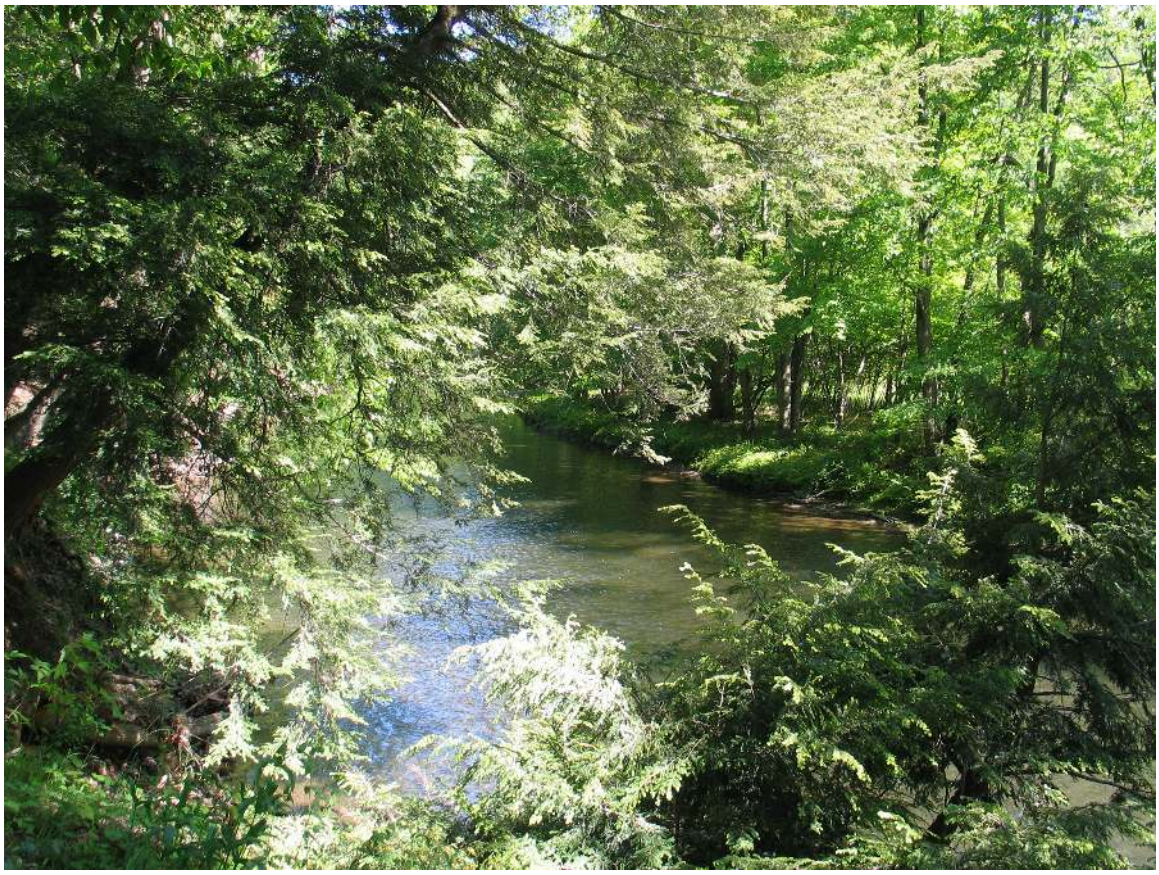
[13] P.S. Kourtev, W.Z. Huang, and J.G. Ehrenfeld. 1999. "Differences in earthworm densities and nitrogen dynamics in soils under exotic and native plant species," *Biological Invasions* 1:237-245.

prevent surges in sedimentation and pollution, filter and absorb certain pollutants, and prevent erosion.



These riparian forest buffers, similar to that shown in the above **Figure 6** (Riparian buffer), are especially important for small, pristine streams, like those found in our region, which can otherwise become suddenly overwhelmed by even a single event (flooding, pollution spill, etc.) leading to long-term ecological disruption.[14] (Note: Japanese Stiltgrass and Japanese Barberry appear in the lower left corner of **Figure 6**).

Invasive plant species threaten to replace riparian buffer zones in the Brodhead Watershed as large populations of only one or two species replace diverse native species (these regions are shown on our maps as an invasive density of level "4").

Many of the most widespread invasive plant species found in the watershed by the BWA, such as Japanese knotweed, multiflora rose, and Japanese stiltgrass, do not function as well as native plants at preventing erosion and pollution in regional streams.

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[14] Lowrance 1997

Recommendation: Efforts to remove invasive plant populations for improved stream quality and ecosystem functioning must consider replacing these invasive plants with native species commonly found along streamsides in our region.[15]

[15] See below for more information on native species replacements for invasive plants.

C4. Invasion Vectors: How have these plant species invaded our region?

Invasive plant species have been introduced to the United States by humans both directly and indirectly. The causes for these introductions include:

- **Agricultural purpose**: various plants have been brought from other continents as sources of food or companion plants, and then unintentionally (but inevitably) released into local ecosystems.

- **Horticultural purpose**: many of the invasive plant species in the Brodhead Watershed were originally introduced to the United States by florists and gardeners, and indeed continue to be available from nurseries today.[16] Japanese knotweed and Japanese barberry are two examples of extremely detrimental invasive plants introduced by horticulturalists.[17]

Figure 7. Advertisement for Japanese Barberry.

- **Inadvertent introduction**: seeds and living plant tissue have often been transported to the United States unintentionally, whether along with agricultural or horticultural seeds or simply on cargo ships and trains, on immigrants and travelers, and on transported livestock and animals.

The ability of a plant species, once introduced, to invade the ecosystems it encounters—the species' *invasiveness*—does not follow a simple formula.[18] Some introduced plant species escape predators and diseases found in their original region, allowing them to

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[16] Figure 7, above, is an Internet advertisement from a well-regarded university extension service offering invasive plants such as Japanese Barberry as a recommended landscape alternative. Accessed at: http://urbanext.illinois.edu/ShrubSelector/detail_plant.cfm?plantid=324 [June 2011].

[17] Bossdorf 2005; Barney 2006.

[18] Rejmanek 2000, Willis 1999, Lortie 2004.

grow and spread unchecked in the new region.[19] Relatively efficient use of resources,[20] greater tolerance of stress,[21] or the release of chemicals that inhibit the growth of other plants[22] may allow an invasive species to out-compete indigenous plant species. Post-invasion genetic changes,[23] artificial selection for traits promoting invasion by horticulturalists or agriculturalists,[24] and certain genetic architectures[25] can also favor invasiveness.

Recommendation. Educational efforts aimed at private and public property owners, municipal officials, educators and landscapers are critical. However, for the most serious infestations, legislation prohibiting the possession of a variety of invasive plants could be considered. This approach has been adopted by some states.[26]

D. Extent of Invasive Coverage -- Results of Mapping to Date

During the summers of 2006, 2007, and 2008, the BWA organized a large-scale survey of invasive plant species density along major waterways in the watershed. Survey teams always included at least two experts in invasive plant species identification and GIS technology. Species density was determined over an area adjacent to the streambank along 25-meter distances using a 0-4-point scale:

0 absent

1 rare; only one or two plants or patches present

2 scattered; several plants or scattered patches present

3 moderate; several large patches excluding native plant growth

4 very dense; nearly exclusive presence along streambank

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[19] For many years, this was commonly accepted as the primary cause of invasiveness. Attempts to find specific predators or diseases, however, have proven unsuccessful in many cases (most prominently, Japanese Knotweed), leading ecologists to develop more sophisticated and complex theories of invasiveness.

[20] Pattison 1998, Baruch 1999

[21] Richards 2008

[22] Callaway 2000

[23] Siemann 2001

[24] Bossdorf 2005

[25] Lee 2002. The genetics of plant invasions have become increasingly important to ecologists in recent years. Lee argues that the genomes of certain plant species are more responsive to natural selection than others, and thus more capable of adaptation to new and changing environments. High levels of genetic variance, interspecific and intraspecific hybridization, changes in a small number of genes, and drastic genomic rearrangement could all promote invasion. On the other hand, the evolution of ontogenetically plastic traits, such as salt tolerance in Japanese Knotweed (see Richards 2008), can also promote invasion without evolutionary adaptation. Disentangling these myriad factors is a primary goal of current research in invasion biology.

[26] Texas, for example, prohibits the possession of a variety of invasive plants (e.g., duckweed, water hyacinth, salvinia, etc.). http://www.ntwgs.org/articles/illegalAquatics.html#the%20list.

Survey teams were trained to identify many invasive plant species found in the northeastern United States. A total of 778 sites were surveyed, covering about 120 waterway miles in the watershed.

Fourteen invasive plant species were found at several sites in the watershed; *Japanese Barberry, Multiflora Rose, Japanese Stiltgrass, Japanese Knotweed, Garlic Mustard, Invasive Honeysuckles, Tree of Heaven, Oriental Bittersweet, Crown Vetch, Invasive Olive, Spotted Knapweed, Norway Maple, Purple Loosestrife, Common Reed.*

Figure 8. Images of "Top Six" most dense and most numerous invasive plants found in the Brodhead Watershed by survey shown on Table 1 (below).

As shown on Table 1 below, the number of sites where invasives were found and the number at each site differed substantially.

Of these fourteen species, six (marked in yellow on Table 1) were regularly found at moderate to high density in the region: Japanese stiltgrass, multiflora rose, Japanese knotweed, Japanese barberry, garlic mustard, and invasive honeysuckles

The BWA's survey density results (based on the 0-4 scale describe on the preceding page) for these six high-priority species are also presented cartographically (Figs. 3 to 8 in subsequent sections of this document).

Table 1. Summary of Survey Results Ranked from High to Low by Number of Sites Where Species Were Present.

Invasive Plant Species	Number of Sites Present	Number of Sites at Moderate-High Density
Japanese Barberry	399	61
Multiflora Rose	390	90
Japanese Stiltgrass	382	147
Japanese Knotweed	237	104
Garlic Mustard	205	17
Invasive Honeysuckle	144	38
Tree of Heaven	43	0
Oriental Bittersweet	37	3
Crown Vetch	33	6
Invasive Olive	31	2
Spotted Knapweed	30	1
Norway Maple	26	0
Purple Loosestrife	13	2
Common Reed	12	1

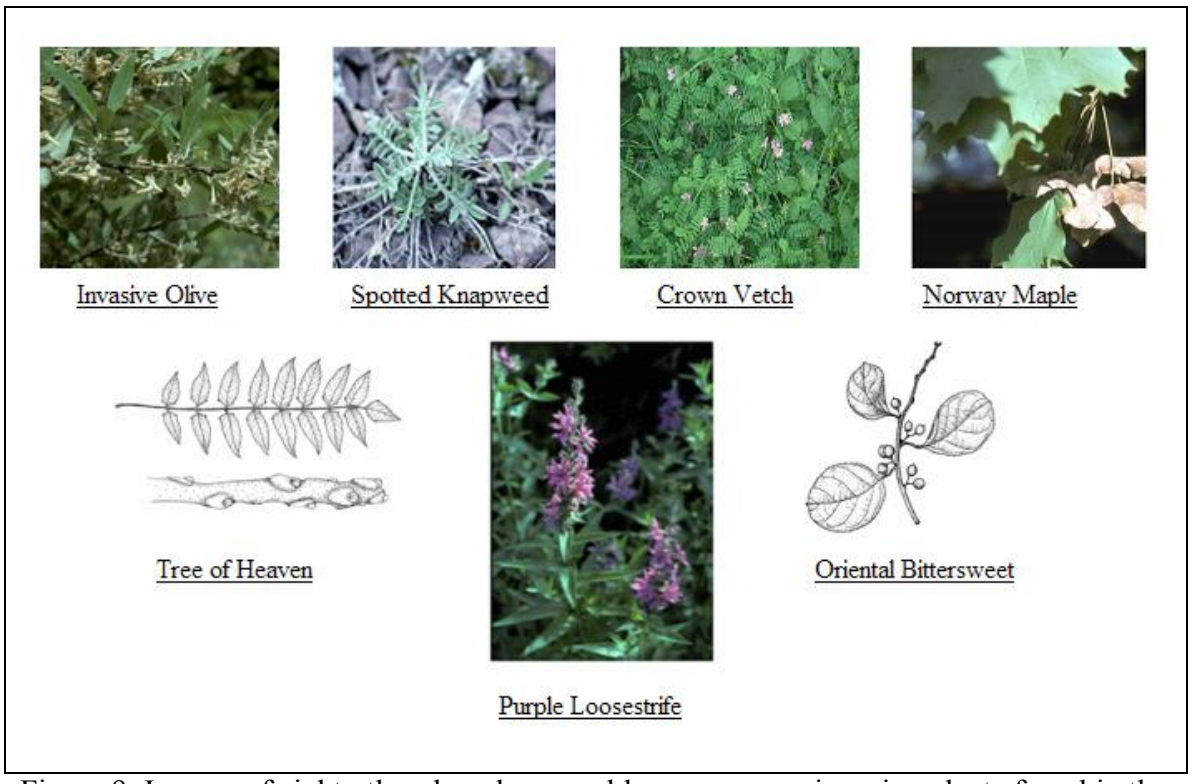

Figure 9. Images of eight other, less dense and less numerous invasive plants found in the Brodhead Watershed by survey shown on Table 1.