Japanese knotweed on the Shawangunk Kill: land use and the effect on success of an invasive species in New York State

William Valleau
University at Albany, State University of New York, wv615694@albany.edu

The University at Albany community has made this article openly available. Please share how this access benefits you.

Follow this and additional works at: https://scholarsarchive.library.albany.edu/legacy-etd

Part of the Biology Commons

Recommended Citation

This Master's Thesis is brought to you for free and open access by the The Graduate School at Scholars Archive. It has been accepted for inclusion in Legacy Theses & Dissertations (2009 - 2024) by an authorized administrator of Scholars Archive. Please see Terms of Use. For more information, please contact scholarsarchive@albany.edu.
Japanese Knotweed on the Shawangunk Kill: Land Use and the Effect on Success of an Invasive Species in New York State

by

William D. Valleau

A Thesis
Submitted to the University at Albany, State University of New York
In Partial Fulfillment of
the Requirements for the Degree of
Master of Science

College of Arts & Sciences
Department of Biological Sciences
2016
Abstract

Japanese knotweed is a highly invasive plant species that is established throughout the United States, including New York State. It is well established in the literature that this plant is spread easily in riparian areas via moving water. In this study, it was hypothesized that the different land use types adjacent to the stream banks would have an additional influence on the spread of the plant. Agricultural and residential land use types were examined as the most likely to demonstrate the land use influence. The area selected for this study was a portion of the Shawangunk Kill, a stream in southern New York State. Locations and sizes of plants, and the observed adjacent land uses, were collected at approximately the same time of year in 2014 and 2015. Establishment rates of Japanese knotweed in areas of residential or agricultural land use were compared to undeveloped areas. Results were evaluated using binary logistic regression to calculate the odds of Japanese knotweed establishment by land use type along the Shawangunk Kill. In 2014 there was a significant relationship observed between residential land use types and Japanese knotweed occurrences. However, in 2015 there was no significant relationship between land use and Japanese knotweed occurrences.
Acknowledgements

This project would not have been completed without the guidance and patience of Dr. Gary Kleppel, Dr. Gary Lovett, and Dr. John Davis. Also special thanks to Daniel Valleau, Shain Valleau, and Michael Valleau for their assistance with field work.

'Maps throughout this document were created using ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license. Copyright © Esri. All rights reserved. For more information about Esri® software, please visit www.esri.com.'
# Table of Contents

Abstract ..................................................................................................................................... ii  
Acknowledgements ................................................................................................................... iii  
Table of Contents ...................................................................................................................... iv  
Introduction ............................................................................................................................ 1  
Intent .......................................................................................................................................... 6  
Methods ...................................................................................................................................... 8  
Results ...................................................................................................................................... 14  
Discussion and Policy Implications ........................................................................................... 21  
Citations .................................................................................................................................... 23
Introduction

The plant commonly known as Japanese knotweed is an introduced plant species in the United States. The plant’s scientific name has changed over time and has been classified as *Reynoutria japonica*, *Fallopia japonica*, and *Polygonum cuspidatum* depending on the source. It was first described by Houttuyn as *Reynoutria japonica* and later as *Polygonum cuspidatum* by Siebold and Zuccarini[7]. In 1988 *Fallopia japonica* was determined to be the most accurate name for the plant by Ronse Decraene *et al.* in the paper examining the limitations of the *Polygonum* genus[12]. The authors utilized a detailed analysis of floral structures as well as review of previous attempts to reclassify the *Polygonum* genus in order to propose a new framework for classification[12]. The Integrated Taxonomic Identification System now lists *Fallopia japonica* as the accepted nomenclature for the plant[13]. References to all three classifications can still be found in recent (post 2000) publications[5][7][8][14][15][16][17][18]. Its other common names include Mexican Bamboo and Japanese Fleeceflower[13].

Two closely related species are Giant knotweed and the hybrid of Giant and Japanese knotweeds, Bohemian knotweed[4]. In the northeastern United States, Japanese knotweed is the main knotweed species of concern. The plant was introduced to the United States in the late 1800’s as an ornamental[5] and by 1880 the plant was naturalized[7]. The plant was imported from its native range in the eastern portion of Asia including China, Korea, and Japan. The USDA PLANTS Database has Japanese knotweed currently occurring in 41 of 50 states, including New York State[11]. The database also breaks down occurrences at the county level and knotweed has been documented in all southeastern NYS counties with the exception of Sullivan and Columbia counties[11].
Botanically, the Japanese knotweed is classified as a geophyte, which utilizes rhizomes for energy storage. The perennial plant has erect stems which can reach greater than 10 feet in height \([4,6]\) (Figure 1A). The leaves are alternating and described as broad and pointed (Figure 1B). The flowers grow in erect branching spikes from the axils and are greenish-white and have five distinct petals \([6,4]\). In the Northeast, the plants typically flower in August and September. The seeds are achenes with three small wings (Figure 1C). It is generally accepted that Japanese knotweed spreads primarily via asexual reproduction in North America, although several studies have identified the potential for sexual reproduction \([4]\). The plant is able to reproduce abundantly from fragments of its rhizomatous root system as well as other vegetative material such as the stems and leaves. The rhizomes can extend more than 5 feet in depth and 50 feet in length \([7]\).
Figure 1: (A) Typical established Japanese knotweed stand in a riparian area. (B) Close up view of leaf shape and flower spikes, and (C) close up of tri-winged acene seeds (Photos by author).
The New York State Department of Environmental Conservation lists Japanese knotweed as a Prohibited Invasive Species. This bans the possession with the intent to sell, import, purchase, transport, or introduce the plant, and also bans people from propagating it. New York State defines an invasive species as “a species that is nonnative to the ecosystem under consideration, and whose introduction causes or is likely to cause economic or environmental harm or harm to human health.” In order to classify a species as invasive the state uses the invasive ranking system established in June 2010 by the New York Invasive Species Council. This ranking system uses a multi-step process to rank the threat posed by potential invasive species. It considers the plant’s ability to spread, the danger posed to residents and ecosystems, and the difficulty in controlling the species. Each invasive plant receives an “Invasiveness Ranking” (0-100) and a category (insignificant, low, moderate, high, and very high). This value is then compared to any beneficial aspects of the species whether they are economic, social, or historical.

This system ranks Japanese knotweed in the “very high” invasiveness category with a ranking of 97.94, which was the second highest score of the 177 plant species assessed in the initial report. It received 40 out of 40 points in the Ecological Impact category based on its documented ability to outcompete native species and form monoculture stands. It received 25 of 25 points in the Biological Characteristics and Dispersal Ability category due to its ability to easily propagate in a wide variety of conditions from small pieces of plant material, its high rate of growth, and the ease of distribution of plant material with water flow and from disturbance and transportation of soil and compost. Twenty three of 25 points were received in the Ecological Amplitude and Distribution category due to its already widespread distribution across the country and New York State, as well as its documented ability to colonize relatively pristine ecosystems such as riparian corridors. Finally, 7 of 10 points in the Difficulty of Control category were received, again due to
its ability to easily propagate from vegetative material and rate of growth. These values were
given a weighted average to account for questions answered as “Unknown” and the invasiveness
score of 97.94 out of 100 was calculated\textsuperscript{[2,3]}. The rhizomes of Japanese knotweed have been documented as being easily spread via moving
water or transported in soil by humans\textsuperscript{[4][7][8][19]}. When the plant establishes itself it is
exceptionally difficult to eliminate. It is very aggressive, crowding out native species\textsuperscript{[7]}. Because
of these characteristics, riparian areas, particularly those with development and human
disturbance along the boundaries are thought to be susceptible to Japanese knotweed infestations.
Once established the plants crowd out other plant species along the banks destabilizing and
increasing erosion in the riparian areas. This then results in waterborne spread of Japanese
knotweed plant material and colonization of new areas, particularly during storm events\textsuperscript{[8]}.
During storm events, higher volumes of water result in greater erosion and transport of larger
portions of plant material, as well as material from plants typically above the waterline.
**Intent**

The spread of Japanese knotweed in riparian areas via water transport has been well established in scientific literature\(^{[19][15][4][20]}\). The purpose of this study is to test the hypothesis that different land uses along a riparian area have an additional influence on the ability of Japanese knotweed to establish and spread in a riparian area. Agricultural land use and residential land use types are hypothesized to be the most likely land use types to demonstrate this influence on establishment as compared to undeveloped land. This study strives to determine if land use affects the ability of knotweed to become established along riparian corridors and examines possible policy implications of the results.

The Shawangunk Kill (“the kill”), located in southern New York (Figure 2A & 2B) was selected as the location for this study due to the presence of Japanese knotweed in its corridor, its importance as an ecosystem in southeastern New York, and the mix of land uses along its corridor. Other riparian areas considered for study were rejected due to either higher density of development, or difficult access. The Shawangunk Kill originates in Greenville, in southeastern New York State and flows approximately 75 kilometers (47 miles) northeast to its confluence with the Wallkill River (Figure 2A). The kill drains a watershed of approximately 236 square kilometers (147 square miles).

The kill is free-flowing, relatively unpolluted, and has limited development in its watershed. The NYSDEC defines the kill as a recreational river from where it forms the border between Orange and Ulster Counties to its confluence. This designation protects the river by requiring permits for various land uses, development of land along the corridor, as well as water withdrawal\(^{[9]}\). The Shawangunk Kill supports various threatened and endangered species, such as pointed watermeal, wingstem, the northern harrier, and the wood turtle\(^{[10]}\). Because of this, the U.S. Fish
and Wildlife Service defines the last 29 kilometers (18 miles) of the kill as a Significant Habitat Complex. This designation is intended to indicate the presence of regionally rare animal and plant populations associated with the river corridor.

Widespread colonization of Japanese knotweed along the Shawangunk Kill would likely result in destabilization of river banks, crowding out of native species, reduction in overall biodiversity, and increased pressure on threatened and rare species in the area. Characterization of the present state of Japanese knotweed infestation and evaluation of the relationship between the plant’s spread and the adjacent land use, can inform and guide development of policies for managing the spread of Japanese knotweed in the Shawangunk Kill and other riparian areas. This study assumes that the primary factor responsible for establishment of Japanese knotweed along undeveloped sections of the kill is downstream transport from other infested areas. By comparing agricultural and residential areas of the stream with the undeveloped areas, a determination can be made as to the extent which development affects the rate of establishment of the plant. Key questions addressed in this study include whether land use significantly impacts the establishment of knotweed and how and relationship between these factors can be utilized to aid in managing the spread of knotweed.
Methods

In 2013, a preliminary mapping and site selection process was conducted along the Shawangunk Kill (Figure 2A). Initial site selection extended from the intersection of the Tomy Kill to the confluence with the Wallkill River (Figure 2B & 2C). Several sections were visited and preliminarily assessed for accessibility and the presence of Japanese knotweed. This involved basic visual surveys of the sections.

The next step was to create land use classifications. This was done by examining aerial photography as well as National Land Cover Database (NCLD) datasets (Figure 3A) to assign preliminary land use classifications along the kill for the study. These included the undeveloped classification for undisturbed forested areas, the residential classification for dwellings and associated yard areas, and the agriculture classification for agricultural lands including row crops, corn fields, hay fields, areas subject to grazing and/or areas to subject periodic mowing not associated with residential areas. Preliminary land use classification was later finalized utilizing field observation to confirm or adjust classifications (Figure 3C).

From the results of the preliminary visual survey, and the preliminary classification of the adjacent land uses, a ~2.8 kilometer (1.75 mile) section of the kill bounded by Shawangunk Lake Road and Ulsterville Road (Figure 2C & 2D) was selected for the study. The site was the most suitable for study at the time because of the confirmed presence of Japanese knotweed, accessibility, and mix of land use along the riparian area (Figure 3A & 3B). The dominant land use in the study area is agricultural. This includes crop fields, hay fields, and overgrown (abandoned) meadows. The length of the study area was as large as reasonably possible with the resources available.
**Figure 2:** (A) The extent of the Shawangunk Kill in relation to the Northeast United States, (B) the extent of the Shawangunk Kill in relation to the Southeast New York and its confluences with Tomy Kill and the Wallkill River, (C) the study area in relation to the confluences with Tomy Kill and the Wallkill River, and (D) aerial view of study area.
Figure 3: Preliminary land use classification was determined using NCLD data (A) and aerial photography (B). (C) The final land use classification for this study based on NCLD data, aerial photography and field observation.
For this study a buffer was defined as the undisturbed area between the land use and the bank of the kill. The buffer size category cutoff was selected as the approximate midway point between smaller and larger buffer areas observed in the study area. This was done in an attempt to differentiate between smaller buffer sizes and larger buffer sizes in allowing colonization of knotweed in the different land use categories.

The Japanese knotweed size category was selected to differentiate between the smaller, younger plants and the older, larger plants. The intent was to determine if newer, smaller plants were establishing with any significant relationship to one of the land use types and/or buffer sizes. The size cut off of 0.1 square meters was selected based of the plants growth habit, as plants established for a longer period of time will have more below ground lateral growth and thus a larger footprint\(^4\)[8][2][11].

Field observations and measurements were conducted in early September 2014. September was chosen to ensure that the Japanese knotweed plants were at or near full seasonal maturity to aid in identification\(^4\)[11][2]. The length of the study area was walked on both the north and the south banks of the kill. The location of each Japanese knotweed occurrence was recorded with a Garmin Etrex 20 handheld Global Positioning System (GPS) unit. In addition, characteristics about the location of the occurrence were recorded. These included the field observed land use at the site (agricultural, residential, or undeveloped based on visual assessment and correlation with aerial photography, see Figure 3C), buffer size category (greater than 10 meters, and less than or equal to 10 meters), and Japanese knotweed plant size category (greater than 0.1 square meter footprint, and less than or equal to 0.1 square meter footprint).
The field data were organized in Microsoft Excel and imported to ArcMap 10.2. Using ArcMap, the occurrences were mapped utilizing each data point’s latitude and longitude. Many observed occurrences consisted of long sections of Japanese knotweed that were indistinguishable as separate plants. In these cases, start and end GPS coordinates were taken. In order to accurately account for these types of occurrences the length of the study area was divided into 5-meter-long sections, each with a north and south bank sub section. The observations were then associated with these sections based on the GPS location. If an occurrence of Japanese knotweed spanned multiple sections it is considered multiple occurrences. This allowed for comparison and analysis of the larger continuous occurrences of the plant, giving more weight to the larger occurrences that spanned multiple sections. The distance between sections containing Japanese knotweed was calculated to include the next downriver section on the same bank and the next downriver section on either bank. This was done by counting the sections between occurrences and multiplying by 5 meters (section length). The distance between plants was used to attempt to determine any relationship between plant locations and spread of new plants.

A master dataset was constructed in Excel which assigned a value for each of the following variables to every section: presence of Japanese knotweed (yes, no), Japanese knotweed size (N/A [for sections with no Japanese knotweed present], small, large), buffer size (N/A [for undeveloped adjacent land use], small, large), distance to next downstream occurrence on same bank (in 5 meter intervals), distance to next downstream occurrence on either bank (in 5 meter intervals), distance to prior upstream occurrence on same bank (in 5 meter intervals), distance to prior upstream occurrence on either bank (in 5 meter intervals), and adjacent land use (undeveloped, residential, agriculture). Categorical variables were recoded with binomial dummy variables in order to allow for statistical analysis.
The data were analyzed using the SYSTAT 13 statistical package to determine if there were any statistically significant relationships in the dataset in order to answer the questions posed above. Due to the categorical nature of the majority of the variables including the presence of Japanese knotweed, land use type, and buffer size, logistic regression models were used. Logistic regression estimates probabilities and odds ratios in order to determine the likelihood of the independent variable returning the reference value based on the values of the independent variables. As the presence of Japanese knotweed at a section is binomial (1 for yes, 0 for no) logistic regression is the appropriate choice.
Results

The field data indicated that there is an established presence of Japanese knotweed, in various states of its life cycle, along the portion of the Shawangunk Kill studied. In both 2014 and 2015 a total of 1116 sections were surveyed along the Kill. In 2014 there were 194 sections containing occurrence of knotweed and in 2015 there were 197 sections. Knotweed was observed in sections with each of the three classes of land use present in the study area (Undeveloped, Residential, and Agricultural). Japanese knotweed occurrence distribution rates, as both a percentage of the total occurrences and a percentage of sections by land use, are compared to land use type distribution rates in Figure 4.

The dominant land use in the study area is agricultural. This includes crop fields, hay fields, and overgrown (abandoned) meadows. The majority of Japanese knotweed occurrences are associated with agricultural land use. Looking at Figures 4A&B it is noted that the distribution of residential occurrences is 8% greater than the distribution of residential land use sections in 2014 and 4% greater in 2015.
Figure 4: Results from surveys conducted in September 2014 (A, top) and 2015 (B). The graphs represent the Japanese knotweed distribution data as percentages of the total occurrences and percentage of sections by land use. Land use distribution did not change from 2014 to 2015.
The results of a logit regression for 2014 occurrences of Japanese knotweed against land use are shown in Table 1. It is apparent that there is a statistically significant (>95% confidence) difference between the odds of a residential section of the Kill having Japanese knotweed present versus an undeveloped section of the Kill (Table 1). Residential sections are two and a half times more likely to have Japanese knotweed present. The likelihood of Japanese knotweed occurring in agricultural sections was not found to be significantly different from undeveloped sections.

**Table 1:** Occurrences of knotweed on residential and agricultural sections are compared against undeveloped sections using a logit regression for 2014. N=194 as the total number of occurrences for that year. LU_14_RES represents residential land use occurrences. LU_14_AG represents agricultural land use occurrences.

<table>
<thead>
<tr>
<th>JK_2014</th>
<th>Reference level 1</th>
<th>Coefficient</th>
<th>Undeveloped</th>
<th>Residential</th>
<th>Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>β₀</td>
<td>0.667</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LU_14_RES</td>
<td>β₁</td>
<td>0.283</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LU_14_AG</td>
<td>β₂</td>
<td>0.941</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>y*=β₀+β₁X₁+β₂X₂</td>
<td></td>
<td></td>
<td>0.667</td>
<td>0.950</td>
<td>1.608</td>
</tr>
<tr>
<td>p=exp(y*)/(exp(y*)+1)</td>
<td></td>
<td></td>
<td>0.661</td>
<td>0.721</td>
<td>0.833</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td></td>
<td>0.005</td>
<td>0.000</td>
<td>0.186</td>
</tr>
<tr>
<td>Odds Ratio</td>
<td></td>
<td></td>
<td>1</td>
<td>2.563</td>
<td>1.327</td>
</tr>
<tr>
<td>95% Confidence Ratio does not include 1</td>
<td>N/A</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A logit regression for 2015 occurrences of Japanese knotweed against land use is was also conducted. The significant difference (>95% confidence) between undeveloped and residential land use is no longer present in 2015 (Table 2).
Table 2: Occurrences of knotweed on residential and agricultural sections are compared against undeveloped sections using a logit regression for 2015. N=197 as the total number of occurrences for that year. LU_15_RES represents residential land use occurrences. LU_15_AG represents agricultural land use occurrences.

<table>
<thead>
<tr>
<th>JK_2015</th>
<th>Reference level 1</th>
<th>Coefficient</th>
<th>Undeveloped</th>
<th>Residential</th>
<th>Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>β₀</td>
<td>1.067</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LU_15_RES</td>
<td>β₁</td>
<td>0.482</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LU_15_AG</td>
<td>β₂</td>
<td>0.172</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

\[ y^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \]

\[ p = \frac{\exp(y^*)}{\exp(y^*) + 1} \]

<table>
<thead>
<tr>
<th></th>
<th>1.067</th>
<th>1.549</th>
<th>1.239</th>
</tr>
</thead>
<tbody>
<tr>
<td>P value</td>
<td>0</td>
<td>0.07</td>
<td>0.397</td>
</tr>
<tr>
<td>Odds Ratio</td>
<td>1</td>
<td>1.188</td>
<td>1.619</td>
</tr>
<tr>
<td>95% Confidence Ratio does not include 1</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Figure 5 is a schematic representation of the locations and sizes of the plants in the two survey years. The distribution of large and small plants also changed over time (Figure 5). 12% of small plants in 2014 were recorded as large plants in 2015. Twenty percent of large plants in 2014 were recorded as small plants in 2015. In addition, new plants have appeared in 2015 that were not present in 2014. 33% of large plants and 61% of small plants recorded in 2015 were not present in 2014. 38% of large plants and 61% of small plants that were present in 2014 were no longer observed in 2015.
Figure 5: Large plants are represented by a green circle and the small plants are represented by a blue circle. The scale of the y axis is 5 meters per increase in value of 1 (Each value of one represents a section in the study area). Several examples of change over time are show explained in the graph margins.
Further analysis including the size category and buffer size category were conducted in an effort to examine the effects on Japanese knotweed distribution. In this study the plant size category was initially created to act as a proxy for the age of any particular occurrence. However, after analyzing the data and as illustrated by Figure 5 above, this is not valid. Large plants were observed to no longer be present in 2015 and new large plants were observed in 2015 were there was previously no occurrence. Although not useful as an age proxy, the size category of the observed occurrences can still provide additional information into the spread of the Japanese knotweed. A dataset of only locations where Japanese knotweed occurred was created and analyzed using the statistical program SYSTAT 11. The dependent variable used was plant size and was analyzed using a logistic regression against land use and buffer size category. The results for 2014 are shown in Table 3.

**Table 3:** Occurrences of Japanese knotweed plants on residential and agricultural sections with small and large buffers using undeveloped sections as a constant are analyzed with large plants as the reference value using a logit regression for 2014. N=194 as the total number of occurrences for that year.

<table>
<thead>
<tr>
<th>JK_14_LRG</th>
<th>Reference level 1</th>
<th>Coefficient</th>
<th>Undeveloped</th>
<th>Agricultural</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Small Buf</td>
<td>Large Buf</td>
<td>Small Buf</td>
</tr>
<tr>
<td>Constant</td>
<td>$\beta_0$</td>
<td>-2.027</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LU_14_AG*BUF_14_SML</td>
<td>$\beta_1$</td>
<td>2.263</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LU_14_RS*BUF_14_SML</td>
<td>$\beta_2$</td>
<td>1.037</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LU_14_AG*BUF_14_LRG</td>
<td>$\beta_3$</td>
<td>2.943</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LU_14_RS*BUF_14_LRG</td>
<td>$\beta_4$</td>
<td>2.432</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\[
\gamma = \frac{\exp(y)}{\exp(y) + 1}
\]

<table>
<thead>
<tr>
<th></th>
<th>$p$</th>
<th>p-value</th>
<th>Odds Ratio</th>
<th>95% Confidence Ratio does not include 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\gamma$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$p=\exp(y)/\left(\exp(y) + 1\right)$</td>
<td>0.116</td>
<td>0.001</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>0.559</td>
<td>0.004</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Odds Ratio</td>
<td>9.615</td>
<td>0.009</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.978</td>
<td>0.059</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.82</td>
<td>0.001</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.387</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: LU_14_AG*BUF_14_SML represents agricultural land use occurrences with small buffers. LU_14_AG*BUF_14_LRG represents agricultural land use occurrences with large buffers. LU_14_RES*BUF_14_SML represents agricultural land use occurrences with small buffers. LU_14_RES*BUF_14_LRG represents agricultural land use occurrences with large buffers.
Table 4: Occurrences of Japanese knotweed plants on residential and agricultural sections with small and large buffers using undeveloped sections as a constant are analyzed with large plants as the reference value using a logit regression for 2015. N=197 as the total number of occurrences for that year.

<table>
<thead>
<tr>
<th>JK_15_LRG</th>
<th>Reference level 1</th>
<th>Coefficient</th>
<th>Undeveloped</th>
<th>Agricultural</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Small Buf</td>
<td>Large Buf</td>
<td>Small Buf</td>
</tr>
<tr>
<td>Constant</td>
<td>β₀</td>
<td>1.774</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LU_15_AG*BUF_15_SML</td>
<td>β₁</td>
<td>0.305</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LU_15_RS*BUF_15_SML</td>
<td>β₂</td>
<td>-1.345</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LU_15_AG*BUF_15_LRG</td>
<td>β₃</td>
<td>-2.873</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>LU_15_RS*BUF_15_LRG</td>
<td>β₄</td>
<td>-1.339</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

|                   |                   |             |             |              |              |
|                   | y*                | 1.774       | 2.079       | -1.099       | 0.429       | 0.435       |
|                   | p=exp(y*)/(exp(y*)+1) | 0.855   | 0.889       | 0.250        | 0.606       | 0.607       |
|                   | pvalue            | 0.121       | 0.475       | 0.02         | 0.229       | 0.255       |
|                   | Odds Ratio        | 1           | 1.357       | 0.057        | 0.26        | 0.262       |

Key: LU_15_AG*BUF_15_SML represents agricultural land use occurrences with small buffers. LU_15_AG*BUF_15_LRG represents agricultural land use occurrences with large buffers. LU_15_RES*BUF_15_SML represents agricultural land use occurrences with small buffers. LU_15_RES*BUF_15_LRG represents agricultural land use occurrences with large buffers.

In 2014 a relationship was observed between buffer size, land use, and Japanese knotweed plant size (Table 3). According to the model an agricultural section with a small buffer size was 9 times as likely to have a large occurrence of Japanese knotweed as an undeveloped section. Agricultural sections with a large buffer were 18 times as likely to have a large occurrence rather than a small occurrence. Residential sections with large buffers were 11 times as likely. There was not a between residential sections with a small buffer and large occurrences of Japanese knotweed. The strong relationship between land use, buffer size and Japanese knotweed size was absent in 2015 (Table 4). However upon review of the data for this model and according to a study by Peduzzi et al 1996[^221], there were not enough data points for every category in the model. This causes the model to behave erratically resulting in the false data above.
Discussion and Policy Implications

The results of the study show the extent of Japanese knotweed establishment along the study area of the Shawangunk Kill, part of a significant habitat complex. Based on the overall findings of this study, and while there were significant relationships between land use and knotweed occurrence calculated in 2014, the results of this study cannot conclude that there is a significant relationship between the occurrence of Japanese knotweed along the Shawangunk Kill and the surrounding land use type or buffer size. The lack of a significant result in 2015 indicates that further data is needed if a relationship is to be established. Continued monitoring of the study area could shed more light on any relationship that may or may not exist. Further study of the mechanics of downstream transport, including erosion, storm events and deposition along the Shawangunk Kill would also be beneficial to understanding the driving forces behind colonization of Japanese knotweed along the Kill. Once a better understanding of Japanese knotweed spread along the Kill is established, control methods may be better evaluated to allow for efficient use of resources.

One of the principal challenges to controlling Japanese knotweed is its ability to spread rapidly, in particular in riparian areas where water flow allows plant debris to spread to multiple sites quickly. This leaves two courses for management of knotweed. First, is to prevent the initial establishment of the plant along riparian corridors. In order to do this effectively a relationship between land use and occurrence of Japanese knotweed would need to be established. If it were, then land use of private lands would need to be regulated along the entire stretch of a riparian area. As most riparian areas are prime agricultural and residential properties this sort of intervention would likely be unpopular. Additionally, if a plant were to become established along riparian areas in spite of land use regulation, this study suggests that that type of control would
be rendered useless on its own. The second and likely more common course of action would be to attempt control the plant after it has become established as it has in the study area of the Shawangunk Kill. Various means are available for the plants’ control including herbicides, cutting, burning, excavation, disease/pathogen introduction, pest introduction, and grazing. All of these have their limitations and likely many would need to be integrated to be successful. Disease/pathogen introduction, and pest introduction are centralized approaches that are outside the realm of possibility for individual landowners to conduct and research is ongoing into their effectiveness. Depending on the size of the occurrence excavation could be prohibitively expensive, and the plant material would need careful handling to prevent unintended spreading. Cutting introduces even more potential for spread especially if mechanical mowing is utilized, and multiple mowings are required for control. Burning and herbicides require multiple applications as well and care must be taken to avoid damaging other plant and animal species. Grazing of the plant in riparian areas would require intensive management practices to avoid damage to the riparian ecosystem and ensure focus on the target grazing species. This method will also require multiple applications for proper control. These kinds of time and resource-intensive are unappealing from a centralized perspective. The answer may lie in a decentralized approach, relying heavily on landowner participation, to control the plant. This would most likely look like a partnership between private land owners and municipalities, with land owners conducting or contracting out the control method and the municipality providing some incentive to do so.
Citations


