THE SPATIAL DISTRIBUTION OF JAPANESE KNOTWEED (*F. JAPONICA*) IN THE CRUM WOODS OF SWARTHMORE COLLEGE IN SPRING 2006

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Abstract

Invasive species are a common problem in natural systems. The first step for any successful ecosystem management effort is to determine the spatial distribution of that species within the invaded habitat, as it identifies areas in most need of attention as well as the major modes of dispersal. In this study we determine the spatial distribution of Japanese knotweed, *F. japonica* in the Crum Woods, Pennsylvania, using Global Positioning System (GPS) and Geographic Information System (GIS) software. We identify three alternative modes of dispersal other than vegetative regeneration- water, disturbance, and sexual reproduction. Our distribution maps illustrate that the overwhelming majority of Japanese knotweed patches are located within ten meters of the banks of the Crum Creek, and that these locations are predominantly flat. Few stands grow along steep slopes more than ten meters away from the creek. Although this study provides much insight about the growth patterns of Japanese knotweed, we suggest that a multi-year research project will be needed to accurately inform possible conservation strategies.

Introduction

Determining the spatial distribution of an invasive species is the first phase of an effective management program (Rew et al. 2006). Mapping an invasive species' distribution aids conservation in four major ways. First, it identifies the most important areas for conservation. In general, priority should be given to the healthiest patches, as severely degraded areas cannot deteriorate any further (Latham et al. 2003). Second, mapping an invasive species allows land managers to make important inferences regarding the biology of the species of interest. This kind of information is particularly useful because often the natural history of invasive species in their introduced range is not well described. Third, comparing maps made over several years helps visualize fronts of invasion and determine the most important modes of dispersal. Finally, knowing the spatial distribution of a species informs conservation strategies.

Japanese knotweed (*F. japonica)* is a severely invasive plant in the Crum Woods, a 77-hectare tract of forested land on the Swarthmore College Campus in Swarthmore, Pennsylvania (Latham et al. 2003). Before strategies for control and eradication can be developed and instated, it is necessary to determine the extent of the invasion and locate the patches of Japanese knotweed in the Crum Woods. We mapped Japanese knotweed patches in the Crum Woods using the Global Positioning System (GPS) and a Trimble ProXR receiver. Maps were created using our GPS data and files from the Natural Lands Trust using ArcView 9.x Geographic Information System (GIS) software. Because GPS/GIS techniques are method-intensive and unfamiliar to most ecology students, determining the most effective way to collect, manage, and process data occupied a large fraction of our efforts. To facilitate future extensions of our project and reduce the amount of time spent fiddling, fussing, and finagling, we include an extensive methods section in this report.

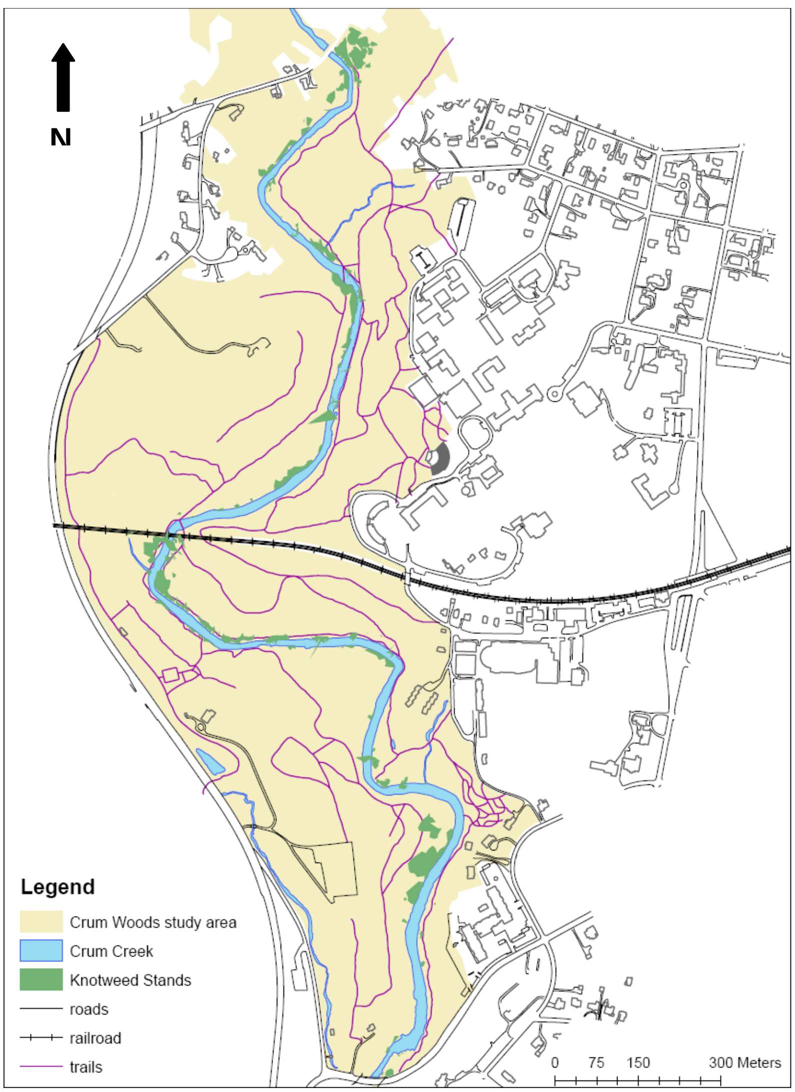

Figure 1. Study area and general distribution of *F. japonica* in the Crum Woods of Swarthmore College.

We found that the banks of the Crum Creek are heavily invaded by Japanese knotweed. We also observed that Japanese knotweed does not grow on steep banks. In addition to vegetative propagation, we suggest that water, disturbance, and sexual reproduction contribute to the dispersal of Japanese knotweed. These observations establish the foundation for future work with the Japanese knotweed populations in the Crum Woods.

MATERIALS AND METHODS

Equipment.

We used a Trimble ProXR GPS unit with Asset Surveyor software to map knotweed stands, PCR sample sites, and soil transect sites in the Crum Woods. ProXR system equipment is described in detail in Chapter 4 of the ProXR Receive Manual; a schematic of the GPS ProXR cabling is shown on page 4-4. In general, the ProXR receiver manual is a good source for basic information about GPS and the ProXR equipment. See Appendix 1 for more information on the various manuals and references available.

The ProXR system requires three sets of batteries for operation. The most conspicuous of these are the 12-volt camcorder batteries that power the ProXR receiver in the field, and are charged in the large yellow battery charger in Prof. Machado's lab. These batteries can be purchased at any battery supplier. In addition, two sets of batteries power the TDCI (handheld) unit: two standard 9-volt batteries and two 3-volt lithium backup batteries. All three sets of batteries must be charged for the ProXR system to function.

The first time we used the TDC1 after it had been in storage, we performed a cold boot. To perform a cold boot, hold the F1, F4, and Enter keys down together while the TDC1 is turned off. While holding them down, press and release the On/Off key. (See TDC1 Asset Surveyor Software User Guide page 2-4).

Data dictionary.

Before collecting data in the field, we created a data dictionary in Pathfinder Office. We established a data dictionary with 5 features: knotweed stand, soil transect, knotweed canopy, PCR sample site, and vertex. A description of each of these features is presented in Table 1, and Appendix 2 details the structure of the data dictionary. Future researchers who wish to combine their datapoints with ours should use the same data dictionary because features must have the same attributes to be combined into one layer in ArcView software. A copy of our data dictionary is saved as "Knotweed Study.ddf" in the Pfdata folder on the C drive on the computer in J.-L. Machado's research lab. A complete description of how to create a data dictionary can be found in the Pathfinder Office Software manual Volume 2.


Figure 2. Plotting a vertex with the Trimble Pro XR. D. Moore holds the receiver high to aid in locating satellite reception.

Field Methodology

Our sampling method was designed to identify, locate and, map every knotweed stand in the Crum Woods on Swarthmore College property. We used two different variations in the methods. On the east side of the Crum Creek, our data points were taken using shape features, as described in our data dictionary. This meant that several points were taken along the perimeter of the knotweed stand. The exact number of points was not fixed, and was mainly dependent on the size of the stand. The GPS took only one reading from each point along the perimeter instead of averaging many readings, so each vertex had no buffer against inaccuracy.

However, we discovered that the calculated shapes of the mapped knotweed stands were highly irregular and unreliable. In several instances, the GPS coordinates of knotweed stands indicated that they were growing in the creek, when in fact they were several feet away from the bank. Upon discussion this problem with Geoff Compton, we revised this sampling method and instead of using shape features, we decided to take vertices at the corners and important edges of the knotweed stands. Each vertex was an independently calculated point for which 10 GPS readings were taken. There was not a minimum number of vertices that we were aiming for, rather that number was dependent on both the size and the shape of the knotweed stand. The smallest patch that we mapped required only three vertices; the maximum number of vertices we used was 17. When the Crum Creek defined the edge of a knotweed stand, we mapped three sides of the stand, using the river bank as the fourth side to complete the perimeter. Each vertex point was defined by the knotweed stand ID number and a letter ID. For example, vertex 150D denoted the fourth point taken at knotweed sample site 150. The order of the letters was important as the collection of points taken for each stand was then connected into area features using GIS software post data collection. This reduced the amount of error that was build into mapping our stands, as the GPS unit in the field would not have to simultaneously record the location and connect the points to form the shape. However, this increased accuracy required a dramatic increase in labor and time. Due to time constraints, this revised sampling method was only applied to the west side of the Crum Creek, and two sites on the east bank, as we had already mapped the majority of the east side by the time we had our discussion with Mr. Compton.

Due to the wide distribution of knotweed stands in the Crum Woods on Swarthmore College property, the mapping process was spread out over a period of three months. In March, when we first began sampling, knotweed stands were easily identified by the presence of several light brown stalks with distinct raised nodes. The perimeter was thus defined by the outermost ring of these brown stalks. However, towards the end of our mapping period, the new generation of knotweed stalks had already sprouted and some specimens were already well over 2 meters tall. This made determining the perimeter of the stands much harder, as we were only interested in the growth of last year's knotweed stands.

In addition to our own project, we were charged with the task of mapping sampling sites for both the soil transect and the PCR experiment. These were independently selected and flagged by the two groups. Point features were taken for these two types of sampling sites, each comprising ten or more readings.

Feature name	**Feature type**	**Purpose**	**Attributes**	**Purpose**	**Comments**
Knotweed stand	area feature	to map knotweed stands as areas; used only on the east side of the Crum Creek	Site number	Identifies site	
			Sample ID(s)	none	not used
			Site features taken	date density and thickest stem information was collected	not used
			Density	stalks/m	not used
			Thickest stem	circumference of thickest stem, cm	not used
			Samples collected	Identifies PCR samples collected from site	not used
			Genotype sample A	Indicates genotype	not used
			Genotype sample B	Indicates genotype	not used
			Genotype sample C	Indicates genotype	not used
			Genotype sample D	Indicates genotype	not used

			Comment	Comment	
			Extra	Comment	
Soil transect	point feature	to mark the location of the soil transect sites	Site ID	Identifies site	not used
			Cover	Identifies cover (bare, native flora, knotweed)	not used
			Nitrate	Indicates nitrate levels	not used
			Erodibility	Indicates erodibility rating	not used
			Comment	Comment	not used
			Extra	Comment	
Knotweed canopy	area feature	to map the extent of the knotweed canopy as areas; not used	Site number	Identifies site	not used
			Sample ID(s)	none	not used
			Date measured	date canopy information was collected	auto-generated; not used
			Time taken	Time canopy information was collected	not used
			% Cover	Indicates shade density (0 = bright sun, 100 = dense shade)	not used
			Extra	Comment	not used
PCR sample site	point feature	to mark the location of the PCR sample sites	Site number	Identifies site	
			Sample ID(s)	Identifies sample (A or B)	
			Date sampled	Date root material was collected for PCR	
			GPS date taken	Date GPS information was taken	
			Genotype	Indicates genotype	A-H, or unknown (U)
			Thickest stem	circumference of thickest stem, cm	not used
			Comment	comment	

			Extra	comment	
Vertex	point feature	Used to map corners and important edges of stands on the west side of the Crum Creek and two stands on the east side	Site number	Identifies site	
			Sample ID(s)	Identifies vertex (A,B,C…)	
			Site features taken	date density and thickest stem information was collected	not used
			Density	stalks/m	not used
			Thickest stem	circumference of thickest stem, cm	not used
			Comment	Comment	

Table 1. Description of features and attributes used in data dictionary "Knotweed Study.ddf."

Transferring field data to a PC.

We transferred data from the TDC1 to the PC using Pathfinder Office software. We connected the TDC1 to the computer via the camcorder battery charger, although it can be connected directly. We selected "File Transfer" option from the main menu of the TDC1 unit. In Pathfinder Office, we selected "Data Transfer" from the "Utilities" menu. In the Data Transfer dialogue window, we selected the type of file we wanted to transfer (usually data file) under the "Add" button, then opened the data files we wished to transfer. After adding all the desired files, we clicked "Transfer All" to move them to the PC. All files were originally stored in the Pfdata folder of the C drive.

Post-processing the data.

After transferring the data into the Pathfinder Office software, we needed to convert it to a more universal file format. We exported each day's worth of collection data into a new file in the format "ArcView Shapefile Setup," making sure to create and properly name a folder each time because the export program gives the same automatic name each time. Once that was done, we moved the folders with ArcView shapefiles in them into our network folder (Biology 36), and then opened up the ArcCatalog 9.x software. This software is a file-organizing program that is one-half of the ArcView software system, and allows quick viewing of the relationships among files. In ArcCatalog, we opened up the ArcMap (ArcMap is the other half of the ArcView system, and is the visual mapping engine) file “knotweed map” stored in the Biology 36 class folder under “GIS/gps stuff.” This file was the rough draft, working copy of the map, and the working data frame was projected in the Universal Transverse Mercator cartographic projection using the North American Datum of 1983, zone 18 (UTM-18, NAD 83).

Then, with ArcMap open in the background and ArcCatalog in the foreground, we dragged the exported shapefile datasets one at a time into the “knotweed map” window. We then visually verified that each of the associated images lined up with the other datasets already in the file, particularly the “waterbodies” and “buildings” datasets. These datafiles were from the College-commissioned survey of the Crum Woods performed by the Natural Land Trust, an ecological monitoring and restoration consultant. Next, we renamed each shapefile within ArcMap to a unique name, such as “Vertex 202-216,” to ready it for final manipulation. We exported each shapefile (right click on the shapefile name, choose “Data…Export Data”) making sure to use the coordinate system of the data frame (UTM-18, NAD 83) into the folder “Knotweed Spatial Distribution,” and then closed the rough draft “knotweed map” file and opened the final version “Knotweed Spatial Distribution” map in ArcMap. We again used ArcCatalog to drag the finalized, UTM-framed shapefiles into the final “Knotweed Spatial Distribution” map.

Each of the spatial datasets from the eastern side of Crum Creek (colored in green on Fig. 5 a-b), because we had recorded them as shape files, needed very little manipulation in ArcMap.

We combined the separate datasets from each day into a single "KW stand" table (except for the first seven, which were the result of a mistake and had to be imported as simple image files), and used the editor function to clip a few of the more egregiously inaccurate shapes to the edge of the

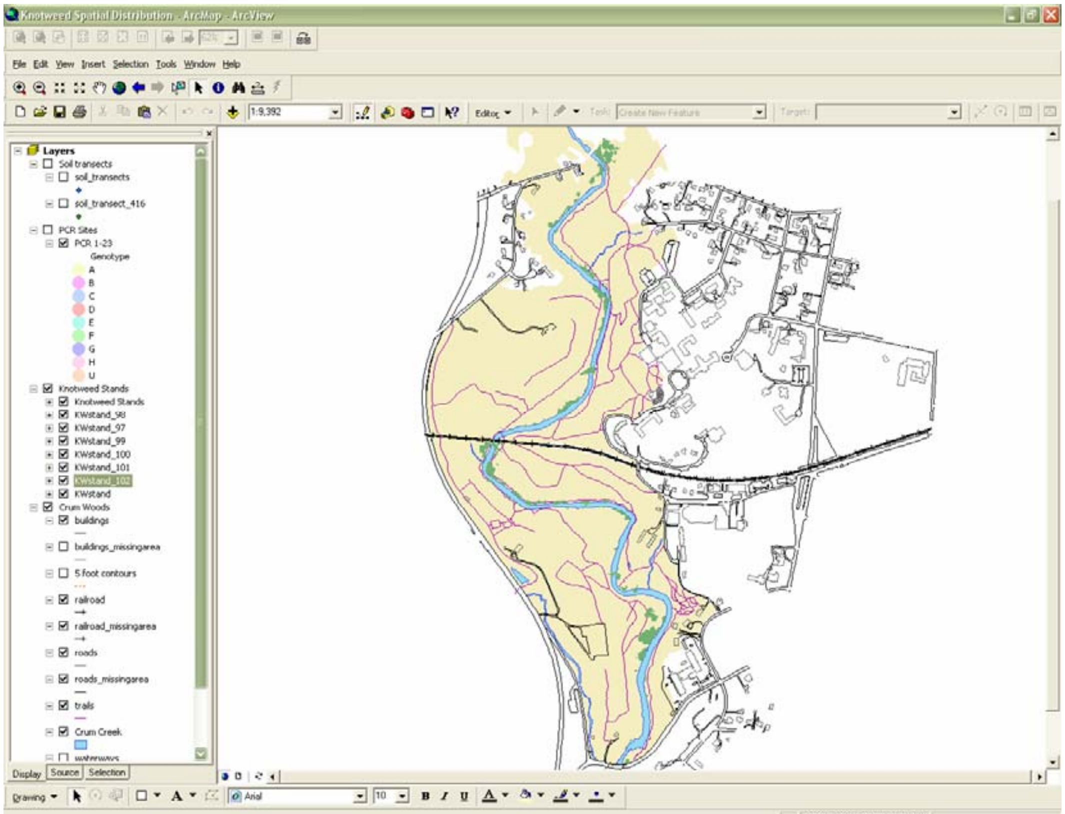

Figure 3. Using ArcGIS 9.x. Visible at left (in ArcMap) are the layers of datasets, and at right is the image produced by combining them.

creek boundary. For the western side (in pink on Fig. 5 a-b) and the southernmost stands on the eastern side, our datasets were in the form of separate vertex points, each averaging together ten readings for accuracy, and numbered as described above. We used a line-drawing editor tool to create shapes from the vertices, snapping the endpoints of each line to the vertices in alphabetical order. We added each of these new shapes (in numbered order) to the same "KW stand" table and, after saving the table, removed the vertex files from the map.

We post-processed the PCR sample site and soil transect site shapefiles in the same way, but they required no further manipulation once we transferred them to the final “Knotweed Spatial Distribution” map.

We created .pdfs for distribution to the rest of our lab team, and formatted several different versions for use in this report. The topographical lines, road and railroad features, trails, and other geographical features were originally part of the Natural Land Trust survey, and we did not manipulate them for use as background and reference datasets in this project.

RESULTS

Japanese knotweed grows extensively in the Crum Woods (Fig. 5 a-b). Growth is concentrated along the banks of the Crum Creek; we observed very few patches that did not abut the creek. The method used for mapping the west side of the creek was more accurate than the method for mapping the east side of the creek.

Figure 4. Immature knotweed on a disturbed path. This photo was taken on the same day as Fig. d. Note the size disparities among individuals.

We observed three sites with exceptionally large Japanese knotweed patches: the floodplain forest just south of Wallingford Road, the Crum Meadow and the area under the railroad trestle, and the floodplain forest east of the composting facility. The most striking similarity between these sites is their flatness. This is true also of sites with moderately sized Japanese knotweed patches. We observed no growth of Japanese knotweed on steep slopes (Fig. 6).

Because we mapped from mid-March through the beginning of May, we were able to observe the regeneration of shoots from underground rhizomes. As has been reported earlier, Japanese knotweed grows vertically at an astonishing rate (Shaw and Seiger 2002). We also observed significant radial spread; it was not uncommon for knotweed shoots to appear 2m away from the closest dead stem from the previous year's growth. It is important to emphasize that our maps underestimate the current extent of Japanese knotweed invasion because we mapped only last year's stalks that survived the winter. If we mapped this year's growth, all patches would be significantly bigger.

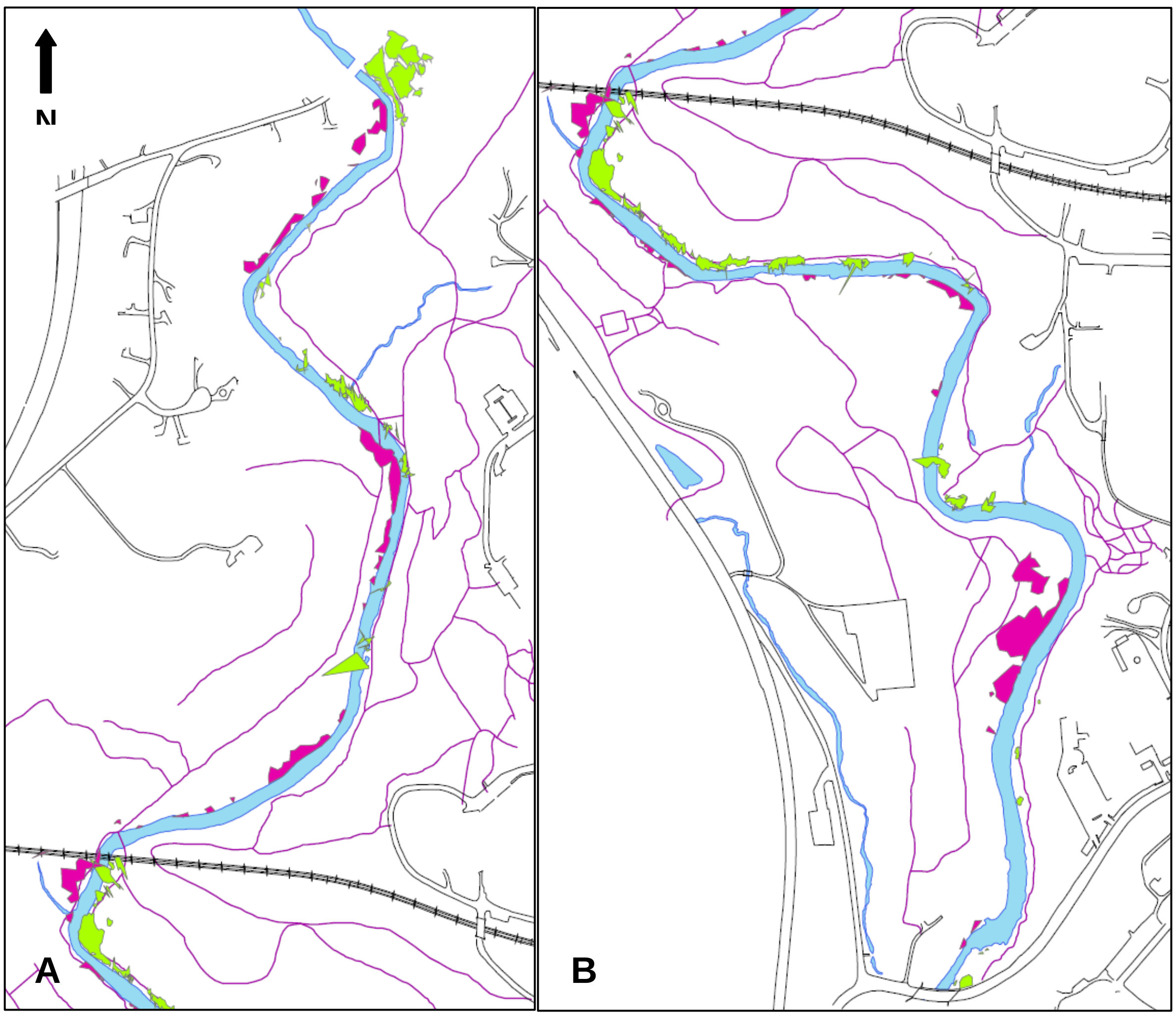

Figure 5. The spatial distribution of *F. japonica* in the Crum Woods of Swarthmore College, Spring 2006. Areas represent the dead stems of the previous year's woody growth. Areas in green on the east bank show the less-accurate, early method of data sampling using area files, while areas in pink on the west bank show the more-accurate, later method of sampling using vertices of multiple GPS readings each. (A) shows the northern half of the study area, above the train tracks; (B) shows the southern half, below the train tracks.

DISCUSSION

Although most literature describes asexual reproduction via rhizome regeneration as the predominant mode of dispersal for Japanese knotweed in its introduced range (Hollingsworth et al. 1998, Hollingsworth and Bailey 2000), our observations in the field suggest other forms of dispersal are important as well. Appreciating the various methods of knotweed dispersal is crucial to the success of any restoration effort to fight the spread of this invasive species.

The most obvious of these alternate dispersal mechanisms is by water. Our spatial distribution map clearly shows that most knotweed stands are located less than ten meters from the Crum Creek bank. This can be explained by the fact that loose fragments or seeds are easily carried downstream and establish new plants once they are land bound again. The extent of knotweed distribution close to the creek, and its almost complete absence further away from the riverbank, points to importance of the water system in the dispersal of knotweed. Periodic flooding may allow knotweed propagules to reach inland sites that are not normally accessible. The presence of large stands of knotweed that cut inland in flood plains supports this interpretation (Fig. 6).

Another form of dispersal we observed occurs appears to occur sites that are frequently disturbed. In areas where vegetation management frequently occurs, such as the PCR sampling site 15A, where the grass and surrounding vegetation was mowed in order to allow easy access by cars, we noted much higher numbers of new stalks growing compared to sites where there were no signs of management. This can be explained by the fact that fragments of rhizome or internode tissue as small as 0.7g or 1cm have been found to be biologically viable and able to grow independently (Soll, 2004). Dispersal via fragmentation is probable in the presence of large animals, such as deer. Movements by these animals could easily break off segments of the stalk. These segments could then drop to the ground and develop into a new plant.

We also found some Japanese knotweed growing in crevices between stones in an old railway trestle. This observation has implications for the reproductive ecology of Japanese knotweed at our site. It is impossible that the Japanese knotweed growing on the trestle grew from rhizomes of nearby Japanese knotweed plant because the stalk would have to have grown through one meter of rock. It is possible that the Japanese knotweed growing on the trestle sprouted from internode tissue that landed in the crevice (Shaw and Seiger 2002), but we suggest this may be indirect evidence of sexual reproduction and dispersal by seeds. Our interpretation is supported by the results of the genetics portion of this study.

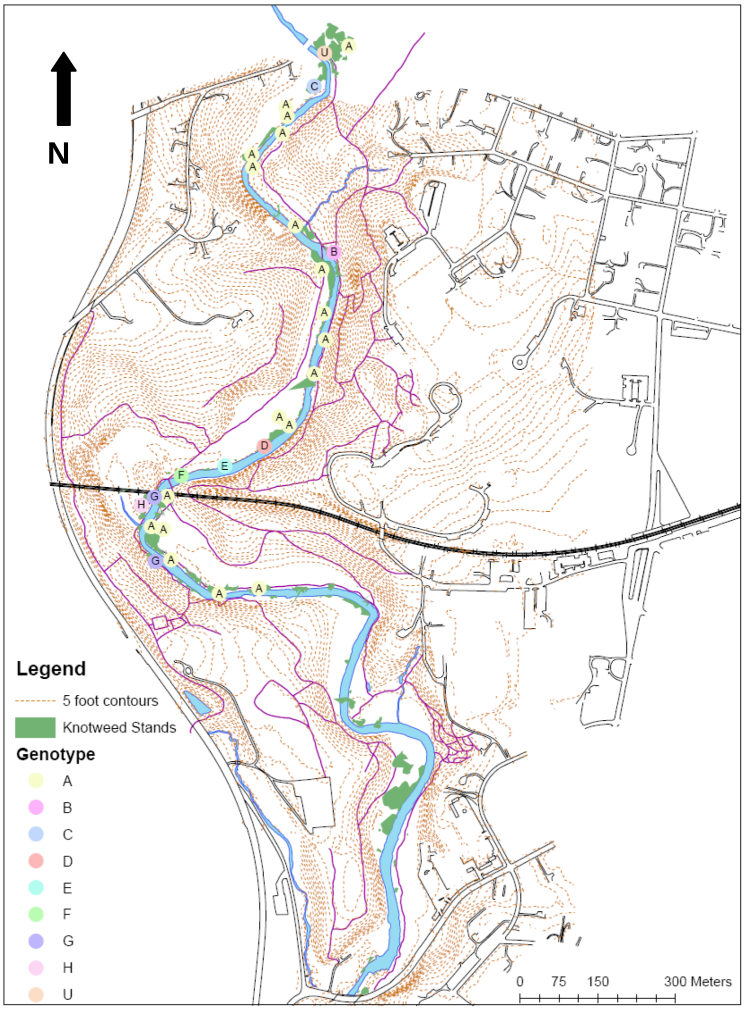

Figure 6. The spatial distribution of knotweed in the Crum Woods of Swarthmore College in relation to topography and genetic diversity. Contour lines represent 5-foot vertical intervals. Knotweed is concentrated in flat, floodplain areas in bends along Crum Creek, and is dominated by one genotype (A).

Regardless of the mode of dispersal, the knotweed stands in the Crum Woods occur in similar habitats. Most knotweed stands grew on relatively flat surfaces, in close proximity to the Crum Creek. Few, if any, knotweed stands were found along the steeper slopes on the western bank of the creek. These sites are usually shaded by tree canopy. We propose that the creek bed provides favorable growing conditions for Japanese knotweed because it is brighter and moister there than in other parts of the Crum Woods. (Shaw and Seiger 2002). The relatively sparse tree cover along the river allows ample light to reach down onto the plant, and the proximity to the river bed provides the necessary water supply for the growing knotweed.

This survey of the Crum Woods serves as a preliminary study in what we hope will become a multi-year comprehensive research project on the growth pattern and rate of dispersal of Japanese knotweed. We hope that an annual mapping of the growth of knotweed from the previous year will shed light on how fast and how far it spreads in a year. This will allow for a calculation of how much time we have to eradicate Japanese knotweed before it is a serious and imminent threat to the biodiversity and ecosystem functioning of the Crum Woods.

Figure 7. Mature knotweed towers over E. Cava in a dense, monoculture stand.

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Appendix 1: Equipment Manuals and their Uses

GPS Mapping Systems: General Reference (Trimble)

This is a good introduction to the concept of GPS surveying and how the GPS technology works. Much information can be gleaned, but we recommend only skimming it briefly to get the big ideas.

TDC1 Asset Surveyor: Software User Guide (Trimble)

This manual is an essential part of the Pro XR library. It describes how to use the piece of equipment we spent the most time with, the TDC1 datalogger, and has clear button-by-button instructions for configuring the system, creating data ("rover") files, taking data points, and using the Waypoint and Route functions to navigate. We highly recommend reading this manual in detail and, after creating a practice data dictionary, keeping it nearby while practicing by taking sample point, shape, and line files.

Pathfinder Office Software: Volume 1 (Trimble)

Volume 1 describes how to use the many features of the Pathfinder Office software program. The first few sections are useful for getting oriented, but we did almost all of our manipulation and post-processing in ArcGIS, and so did not require the detailed information about Pathfinder Office. This manual does, however, contain instructions on using a built-in tutorial of the software, which may be useful.

Pathfinder Office Software: Volume 2 (Trimble)

This manual describes how to construct and use a data dictionary. We highly recommend reading this volume and creating and field-testing a practice data dictionary before attempting to gather data in the field.

Pathfinder Office Software: Volume 3 (Trimble)

Volume 3 describes the steps involved in transferring data from the TDC1 to a PC and also transferring data dictionary and setup files from a PC to the TDC1. It has helpful step-by-step instructions.

Pro XR Receiver Manual (Trimble)

This manual describes the Pro XR equipment setup, and has some very helpful diagrams about how to connect the cords and boxes. Figure 4-3 is the cabling diagram most applicable to our TDC1 setup.

Getting to Know ArcGIS Desktop (ESRI Press)

We did not read this book initially, but it appears to contain clear descriptions of the sorts of functions ArcGIS can do as well as instructions for how to do them. It is specifically written for version 8.x, but many features are the same as version 9.x, the most recent ArcGIS version available in 2006 and the one we used for this project.

"What You Need to Know About Using and Maintaining Your TDC1 Datalogger Batteries."

Describes the procedures for assessing battery life and directions on replacing exhausted batteries.

Available at [http://trl.trimble.com/dscgi/ds.py/Get/File-9716/tdc1batx.pdf].

"Pro XR Support & Training: Downloads."

Contains the latest firmware and software support updates for the Pro XR receiver.

Available at [http://www.trimble.com/support_trl.asp?Nav=Collection-6319]. If the link breaks, simply go to http://www.trimble.com/support.shtml and choose "GPS Pathfinder Pro XR."

Phase Processor: Software User Guide (Trimble)

We did not use this handbook and do not recommend spending time with it.

APPENDIX 2: BUILDING THE DATA DICTIONARY

As of this writing, the Pathfinder Office Software Manual Volume 2 was missing from Prof. Machado's lab, so the following is an outline of the steps involved in creating a data dictionary for use with the TDC1 Asset Surveyor and Pro XR GPS receiver:

- Open GPS Pathfinder Office Software and, when the "choose project" window appears, choose "New project" and give the project a unique name.
- Under the "Utilities" menu, choose "Data Dictionary Editor." Enter the name of the specific dictionary you'll be building in the "Name" field, and a brief description of its purpose in the "Comment" field.
- Save the data dictionary in the project folder created previously.
- Click "New feature…" and name the type of feature you'd like to collect. Choose whether it should be a point, line, or area feature. Point features are the most accurate and are what we used to create vertices of knotweed stands.
    - Under the "Default Settings" tab, enter the minimum number of positions required before storing a feature (in a point file, more features means more accuracy), and the number of seconds between positions logged assuming perfect reception (a shorter interval means less wait to record a feature when satellite reception is good).
    - Under the "Symbol" tab, choose what the feature will display as in Pathfinder Office. When exported as a shapefile, ArcGIS ignores this information, so only use it to distinguish among different features within Pathfinder and don't expend a great deal of energy on choosing perfect symbol representations.
- With the new feature selected, click "New Attribute" to add other data besides the simple GPS position to the feature. Text attributes allow each feature to be named or commented upon, Menu attributes allow the creation of drop-down menus with multiple, constrained choices, Date and Time attributes record either the instantaneous time and date of GPS sampling or some other user-specified time, and Numeric attributes create numeric data fields. There is no workable limit on the number of attributes that can be associated with a feature, but it is helpful to place the most-used or most-important attributes at the top of the list so that it is easier to enter them on the small TDC1 screen in the field. Fig. 8 is a list of the features and attributes we used for this project.

- Once all features and attributes have been described (and it's always a good idea to add more features and attributes than are likely to be needed, in case of unforeseen circumstances in the field, and to have each feature and attribute very clearly labeled), the data dictionary can be imported into the TDC1 for field use via the Data Transfer utility.

```
C:\Pfdata\Knotweed Study.ddf                                                                        5/13/2006
Knotweed UPDATED

Knotweed stand         Area Feature, Label 1 = Density (stems/m2), Label 2 = Thickest stem
                       (stems only)
   Site Number         Text, Maximum Length = 12
                       Normal, Normal
   Sample ID(s)        Text, Maximum Length = 20
                       Normal, Normal
   Site features taken       Date, Month-Day-Year Format, (date)
                       Normal, Normal
   Density (stems/m2)  Numeric, Decimal Places = 2
                       Minimum = 0, Maximum = 200, Default Value = 0
                       Normal, Normal
   Thickest stem       Numeric, Decimal Places = 2, Diameter (cm)
                       Minimum = 0, Maximum = 25, Default Value = 0
                       Normal, Normal
   Samples collected   Date, Month-Day-Year Format, (date)
                       Normal, Normal
   Genotype Sample A   Text, Maximum Length = 30
                       Normal, Normal
   Genotype Sample B   Text, Maximum Length = 30
                       Normal, Normal
   Genotype Sample C   Text, Maximum Length = 30
                       Normal, Normal
   Genotype Sample D   Text, Maximum Length = 30
                       Normal, Normal
   Comment             Text, Maximum Length = 100
                       Normal, Normal
   Extra               Text, Maximum Length = 100
                       Normal, Normal

Soil transect          Point Feature, Label 1 = Site ID, Label 2 = Comment
   Site ID             Text, Maximum Length = 30
                       Normal, Normal
   Cover               Menu, Normal, Normal
      Bare
      Native
      Japonica
   Nitrate             Text, Maximum Length = 100
                       Normal, Normal
   Erodibility         Text, Maximum Length = 100
                       Normal, Normal
   Comment             Text, Maximum Length = 100
                       Normal, Normal
   Extra               Text, Maximum Length = 100
                       Normal, Normal

Knotweed Canopy        Area Feature, Label 1 = % Cover
   Site Number         Text, Maximum Length = 12
                       Normal, Normal
   Sample ID(s)        Text, Maximum Length = 20
                       Normal, Normal
   Date measured       Date, Auto generate Create, Month-Day-Year Format
                       Normal, Normal
   Time taken          Time, Auto generate Create, 24 Hour Format
                       Normal, Normal
   % Cover             Numeric, Decimal Places = 0
                       Minimum = 0, Maximum = 100, Default Value = 0
                       Normal, Normal
   Extra               Text, Maximum Length = 100
                       Normal, Normal

PCR Sample Site        Point Feature, Label 1 = Genotype
   Site Number         Text, Maximum Length = 12
                       Normal, Normal
   Sample ID(s)        Text, Maximum Length = 20
                       Normal, Normal
   Date sampled        Date, Month-Day-Year Format
                       Normal, Normal
   GPS date taken      Date, Auto generate Create, Month-Day-Year Format
                       Normal, Normal
   Genotype            Text, Maximum Length = 30
                       Normal, Normal
   Thickest stem       Numeric, Decimal Places = 2, Diameter (cm)
                       Minimum = 0, Maximum = 25, Default Value = 0
```

Figure 8. Data dictionary features and attributes.

```
                      Normal, Normal
   Comment            Text, Maximum Length = 100
                      Normal, Normal
   Extra              Text, Maximum Length = 100
                      Normal, Normal

Vertex                Point Feature
   Site Number        Text, Maximum Length = 12
                      Normal, Normal
   Sample ID(s)       Text, Maximum Length = 20
                      Normal, Normal
   Site features taken       Date, Month-Day-Year Format, (date)
                      Normal, Normal
   Density (stems/m2) Numeric, Decimal Places = 2
                      Minimum = 0, Maximum = 200, Default Value = 0
                      Normal, Normal
   Thickest stem      Numeric, Decimal Places = 2, Diameter (cm)
                      Minimum = 0, Maximum = 25, Default Value = 0
                      Normal, Normal
   Comment            Text, Maximum Length = 100
                      Normal, Normal
```

Figure 8 (cont). Data dictionary features and attributes.

Appendix 3: Using the Trimble Pro XR

Figure 9. H. Hsu suiting up in the lab to carry out our field equipment. The Pro XR receiver and 12V batteries are in a lumbar pack clipped around his waist, the TDC1 datalogger is in the vertical front pouch, and the antenna is mounted on a yellow pole comprised of several sections for varying length and weight.

- The most recent firmware must be installed on both the TDC1 and Pro XR receiver. To download these updates, see the Trimble support page as described in Appendix 1. Support downloads include instructions for installation.
- We encountered frustrating delays on days with poor satellite reception. We recommend using Trimble's Mission Planning Software, which must be updated with a current satellite status download. An administrator must install the software initially in Prof. Machado's lab. This software should allow the user to plan what days and times will receive the best satellite reception and therefore limit frustrating days in the field waiting for points to resolve themselves accurately. Both downloads are available at: [http://www.trimble.com/planningsoftware_ts.asp].