Extending the Timeframe for Rapid Response and Best Management Practices of Flood-Dispersed Japanese Knotweed (*Fallopia japonica*)

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Extending the Timeframe for Rapid Response and Best Management Practices of Flood-Dispersed Japanese Knotweed (*Fallopia japonica*)

Brian P. Colleran and Katherine E. Goodall*

The objective of this article is to extend the reported period in which flood-distributed knotweed propagules may be successfully managed using only manual labor. During a second round of early detection and rapid response (EDRR) management along the Green River in Guilford, VT, we collected and measured all Japanese knotweed propagules that had been distributed by flooding approximately 21 mo earlier, in August 2011, at a single site. Our data suggest that knotweed *s.l.* prioritizes the growth of new stems over new rhizomes at the start of a growing season. Because the limiting factor for successful removal of new knotweed *s.l.* plants by hand is the size of the rhizome system, our findings support extending the time frame for EDRR management of flood-distributed knotweed *s.l.* into the second spring after its initial dispersal. Additionally, in November 2013, surveys of our work sites found no new knotweed *s.l.* plants in locations accessible to work crews. In addition to validating our EDRR management techniques, this implies that knotweed *s.l.* fragment viability does not extend past the second spring following its dispersal.

Nomenclature: Knotweed *sensu lato*; Japanese knotweed; *Polygonum cuspidatum* Siebold & Zucc.; *Fallopia japonica* (Houtt.) Ronse Decr.; *Reynoutria japonica* Houtt.

Key words: Climate change, early detection, erosion, flooding, knotweed growth, knotweed propagules, knotweed spread, rapid response, riparian invasives, Tropical Storm Irene, volunteer knotweed control.

Early detection and rapid response management (EDRR) of nonnative, invasive species is a best management practice capable of potentially eradicating new invasive species (Westbrooks 2004; Wittenberg and Cock 2001), which is also often the most economically desirable management option (McNeely et al. 2003; Naylor 2000; Rejmánek et al. 2005). Unsurprisingly, this has made it the preferred choice of most land managers (DiTomaso 2000; Rejmánek 2000; Simberloff 2003). Unfortunately, EDRR rarely lives up to its potential in practice (Simberloff 2003). This can be partly explained by the difficulties of managing invasions of ecosystems, which often cross jurisdictional boundaries, and the accompanying change in funding and management priorities those boundaries represent (Dyckman and Hoy 2001).

Although eradication of invasive plants has rarely been obtained on any level once an invasion has reached the regional scale (Rejmánek and Pitcairn 2002), we feel that knotweed *s.l.* presents an opportunity to reasonably set goals for local eradication using EDRR. Although most Japanese knotweed plants we handled were likely *Fallopia japonica* (Houtt.) Ronse Decr., we adhere to the suggestion of Bailey and Conolly (2000) to use the term knotweed *s.l.* (sensu lato, in the broad sense) because most keys to identify species and hybrids of knotweed are inappropriate in New England (Gammon et al. 2007). Once established, knotweed *s.l.* is extremely difficult to kill, and it may have severe economical (Williams et al. 2010), ecological (Aguilera et al. 2009; Gerber et al. 2008; Lecerf et al. 2007; Maerz et al. 2005; Stoll et al. 2012), or infrastructural effects (Elliott 2011; Locandro 1973; Nagel 2012). Although knotweed *s.l.* is certainly capable of sexual reproduction (Bailey et al. 2008; Forman and Kesseli 2003; Gammon et al. 2010), the geographic extent of sexually reproducing knotweed *s.l.* is unknown. Once established, knotweed *s.l.* spreads effectively through fragmentation (Bailey 1994; Colleran and Goodall 2014; De Waal 2001; Rouifed et al. 2011; Sásik and Pavol 2006). This most often takes place after flood events and highway mowing, which limit its distribution to floodplains

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Management Implications

Continuing the summer of 2012 early detection and rapid response (EDRR) work detailed in Colleran and Goodall (2014), we manually eliminated knotweed propagules distributed by Tropical Storm Irene in August 2011 in southern Vermont, during the early spring of 2013. We collected data showing that the period of opportunity can be extended for EDRR management of flood distributed knotweed *s.l.* propagules beyond that which we had previously established.

Additionally, our data showed that knotweed *s.l.* prioritized its spring growth in aboveground biomass, nearly to the exclusion of rhizome growth. The relatively large size of second-year knotweed *s.l.* plants compared with other vegetation in the early spring allows for highly effective visual surveys, whereas their small rhizome network, which had yet to expand from the previous year's growth, allows for effective manual removal of the whole plant.

Although we found no new plants in November 2013 in areas accessible to manual removal, we feel this was only because of the management conducted in May 2013, as a follow-up to our summer 2012 efforts. Knotweed propagules will sprout at any point in the growing season, and significant numbers emerged at managed sites after our 2012 work was completed. The lack of plants in November 2013 suggests that our May 2013 management activities took place after the period for propagules to sprout had closed and, therefore, effectively controlled those that emerged between management efforts.

Based on our experiences, we feel we have developed a viable method to control these plants. We suggest initial removal work be performed during the first growing season to remove the fastest-emerging plants to prevent them from establishing a vigorous rhizome network. Follow-up work must be conducted either after the first growing season or early in the second growing season to ensure eradication of plants that are slower to emerge. Such a strategy is capable of eradicating new knotweed *s.l.* propagules following flood events. Our findings would be complimented by research that explores the effect of various forms of flooding on knotweed propagule creation and distribution.

and roadsides. Effective EDRR management requires detecting new invasive species when metapopulations are scattered, small patches (Moody and Mack 1988). For knotweed *s.l.*, each new propagule-generating event is an opportunity to find and eliminate the resulting scattered small patches, which can be found in predictable geographic and jurisdictional locations.

These small patches can be effectively managed using unskilled, manual labor (Colleran and Goodall 2014). In addition to allowing for volunteer participation, it also removes the need for herbicides or heavy machinery. As knotweed *s.l.* management commonly requires one or the other, if not both herbicides and heavy machinery, this EDRR management option is also less economically taxing. Coupled with the limited land area to survey and a long period in which to perform the work (Colleran and Goodall 2014), EDRR management of knotweed *s.l.* has great potential to restrict the spread of this plant, regardless of the local or regional status of the invasion.

Materials and Methods

As in Colleran and Goodall (2014), we removed knotweed *s.l.* propagules that had been spread by Tropical Storm Irene, using only manual labor. Plant samples were collected for this analysis from a single site during knotweed *s.l.* control efforts on the Green River in Guilford, VT, on May 16, 2013 (42°76′N, 72°67′W). This restriction to a single data-collection site was made because all other locations had already been subject to management activities the previous year. We therefore felt unable to make any definite claims about whether plants had emerged before or after our initial control efforts. Because this uncertainty would cast doubt on any potential conclusions, we excluded those sites from data collection and had only the single site from which to draw our samples. We returned to all sites in November 2013 to visually inspect for knotweed *s.l.* and to evaluate the effectiveness of our methods.

The results of this study are limited by the short-term nature and geographic scope of the data collection. Future research documenting longer-term patterns over a greater area would certainly add power to our analysis. Despite these limitations, we are confident in the patterns we report here, given our relatively high sample size for individual plants measured.

For each sample, we collected all data using the same methods as in Colleran and Goodall (2014), with two exceptions. First, rather than measuring the three longest rhizomes (LRs), and then determining a mean LR; only the longest rhizome was measured. This was done because we were interested in determining whether or not manual labor was still a viable recommendation, rather than observing patterns of growth. Second, we did not divide the samples according to original fragment type because sample sizes limited this comparison.

Statistical analyses of the data were performed using SPSS statistical software (Version 20, IBM Corporation, 1 New Orchard Rd, Armonk, NY 20504-172). For all analyses, quantitative variables were natural-log transformed to meet the assumption of normality. Morphometric comparisons across the different plant collection times—July 2012, September 2012, and May 2013—were compared by ANOVA.

Results and Discussion

Comparing the morphometrics of all plants collected during the three dates, we found that the LR measurements for plants collected in May 2013 were no different than those collected 8 mo earlier in September 2012 (Table 1). Sprout aboveground (SAG) in our May 2013 collection (Table 1) was already approximately one-half of the July 2012 values. Measurements of fragment volume (FV) and sprout belowground (SBG) were no different from September to May (Table 1), suggesting that plants in both collections have similar resources to draw on and are

Table 1. ANOVAs comparing plant growth variables across three collection times.

Variable	Collection	*n*	Mean ± SD[a]	*F*	P value
Fragment volume, cm^3	July 2012	87	315.90 ± 1452.00 a	9.68	< 0.001
	Sept 2012	59	200.82 ± 776.46 b		
	May 2013	37	18.43 ± 61.99 b		
Longest rhizome, cm	July 2012	90	10.47 ± 7.58 a	13.22	< 0.001
	Sept 2012	58	16.72 ± 9.92 b		
	May 2013	33	16.67 ± 10.24 b		
Sprout below ground, cm	July 2012	60	3.79 ± 4.35	2.74	0.069
	Sept 2012	58	7.71 ± 7.23		
	May 2013	37	4.64 ± 4.20		
Sprout above ground, cm	July 2012	60	43.92 ± 24.56 a	86.76	< 0.001
	Sept 2012	58	10.19 ± 6.60 b		
	May 2013	42	25.73 ± 17.31 c		
Sprout total height, cm	July 2012	90	42.41 ± 25.59 a	34.39	< 0.001
	Sept 2012	59	17.59 ± 11.62 b		
	May 2013	44	28.46 ± 17.42 c		

[a] Mean ± SD followed by the same letter are not significantly different by Tukey's honestly significant difference test (P = 0.05).

buried at similar depths. Our interpretation of data is that flood-distributed knotweed *s.l.* plants initially invest their energy in generating new aboveground growth, rather than belowground growth, in the second spring following their dispersal.

A primary limiting factor for successful, manual removal of knotweed *s.l.* as part of an EDRR management strategy is the extent of the rhizome network. Our data, showing that rhizome length did not increase in the second spring after dispersal, provide evidence that supports extending the window for EDRR removal efforts in the northeastern United States. Previously, we could only assert that such work could be performed until the second autumn after dispersal (Colleran and Goodall 2014). Follow up work in the second spring after dispersal allows land managers to remove plants that emerged after or were missed during the initial removal efforts.

Second spring removal efforts are central to successful management of new flood-distributed knotweed *s.l.* In November 2013, we revisited all removal sites to survey for missed plants and to evaluate our effectiveness. We have commonly observed second-year flood debris knotweed *s.l.* in the past, and it is usually about 1-m (3.28 ft) tall. In combination with many plants having dropped their leaves by that point, we chose that time of year to maximize the potential of finding knotweed *s.l.* plants that had been overlooked. During our visual inspection, we were unable to find any new plants across most of the landscape. The exception was at flood debris piles in which crews were not able to safely or effectively work because of site instability, tightly packed flood debris, or both, which prevented effective removal work. If we had not performed the second management visit, we expect we would have found many healthy knotweed *s.l.* plants in our November visit. Additionally, the lack of new plants across so many sites in November 2013 suggests that propagule viability did not extend beyond May 2013.

For the purpose of controlling the spread of this invasive plant, we believe we have determined how and when manual labor–based EDRR techniques can be used to effectively manage knotweed *s.l.* populations distributed along rivers following high-water events, without the need for heavy machinery or herbicides.

Plants must be gently removed from the soil, using care to remove as much of the plant as possible. In sum, two-step management is recommended. Ideally, the first step should take place in the summer after dispersal to eradicate early emerging plants and prevent them from becoming too well established to remove later. The second step should take place in the second spring after dispersal to remove late-emerging plants and take advantage of the visual search aid provided by the significant stem growth during this season. Based on our experiences, using this management protocol may lead to eradication of these plants.

Further research is required to determine the scope, scale, or type of flood event that leads to the generation and distribution of knotweed *s.l.* propagules. Such work would help land managers develop appropriate expectations regarding the spread of this plant.

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