CIPM Research Grants Final Report

Project Title: <u>Effects of hydrologic alteration on Polygonum cuspidatum invasion in riparian ecosystems.</u>

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Proposal Abstract

I propose to assess the effect of hydrologic alteration by dams on exotic species invasion in riparian plant communities in watersheds in two regions of the United States where it is present. The research will be focused on Japanese knotweed (*Polygonum cuspidatum*), one of the predominant invasive plants in riparian systems throughout large parts of the United States, which forms large monocultures threatening native plant diversity. The relationship between hydrologic alteration, Japanese knotweed invasion, and native plant community composition will be determined using a vegetation survey in two tributaries each of the Skagit River in Western Washington and the Delaware River in Upstate New York which vary in terms of hydrologic alteration. The intermediate product of this research will be a model predicting Japanese knotweed invasion success based on flow regime that would be used as the basis for additional research on the effect of hydrologic alteration on exotic species invasion. In addition, a comparison of the dynamics of Japanese knotweed invasion across different regions will allow for increased understanding about how exotic species are able to succeed in widely varying environments. The long-term goal of this research is to devise flow management strategies for rivers affected by dams that promote native species diversity while limiting exotic species invasion across broad scales in riparian plant communities. These management strategies could then be incorporated into dam re-operations to optimize the ecological integrity of riparian zones.

Problem Description

Riparian plant communities are among the most diverse and heavily invaded plant communities in the United States (Naiman et al. 1993; Planty-Tabacchi et al. 1996; Stohlgren et al. 1999; Brown 2002; Brown & Peet 2003), leading to the concern that exotic species may have devastating effects on riparian ecosystem diversity and function. Alteration of the natural flow regime of rivers by dams and other diversion structures may greatly compound exotic species invasion problems in riparian ecosystems both by negatively affecting native riparian plants and by providing new conditions suitable for the invasion of exotic species (Poff et al. 1997; Stromberg 1998; Richter et al. 2003). One implication of this hypothesis is that effective invasive species management in riparian plant communities might be achieved by restoring the natural flow regime (Richter et al. 2003). But, the extent to which this hypothesis is true has not been explored in a wide range of river systems.

Flow regime has been shown to have complex interactions with native plant assemblages in a wide range of ecosystems (Auble et al. 1994; Busch and Smith 1995; Johnson 1997; Mahoney and Rood 1998; Townsend 2001; Richter et al. 2003). The magnitude, frequency, duration, timing, and predictability of flow regime affect a wide variety of processes related to riparian plant communities (Poff & Ward 1989; Richter et al. 2003). For example, on the Roanoke River in Eastern North Carolina, altered timing of flow regime affects oak regeneration in flood plain forests (Townsend 2001). Cottonwood, likewise, requires specific flow regime characteristics related to magnitude and timing in order to successfully regenerate (Mahoney & Rood 1998; Stromberg 1998). In regions with predictable variation in flow regime, riparian plant communities may represent a mixture of specifically adapted species (Poff & Ward 1989). Alteration of this natural range of variability may result in changes to habitat, declines in native species, and new opportunities for invasive species (Poff et al. 1997; Richter and Richter 2000).

Japanese knotweed was selected as the model organism for this research because it is one of the predominant invasive plants in riparian systems throughout large parts of the United States. A native of early successional habitats in East Asia (Kanai & Konta 1987), Japanese knotweed forms large, dense, monospecific stands, 1-3 meters high and often over 1000 m^2 in spatial extent with extensive underground rhizomes. It grows in a wide range of disturbed areas, from roadsides to flooded habitats such as floodplains and bars (Sieger 1997). In 42 vegetation plots I established on the Nolichucky River in Western North Carolina, I found Japanese knotweed most often on bar communities characterized by frequent flooding, high soil fertility, and high light availability.

Japanese knotweed forms large, contiguous colonies that completely shade out native species in what would otherwise be diverse riparian habitats (Beerling et al. 1994; Bram and McNair, in press). For example, vegetation plots with Japanese knotweed on river bars in southeastern Pennsylvania had fewer than 5 native species compared to 40 species per 100 m^2 in river bar plots without Japanese knotweed (Brown, unpublished data). Japanese knotweed has the potential to alter ecosystem properties by changing sedimentation rates through its dense rhizomatous root growth and the extensive areas of exposed soil it creates by shading out other plant species. Since its introduction in the nineteenth century as an ornamental species, Japanese knotweed has spread extensively and is now established in 39 states of the continental U.S. (USDA 2004).

Intermediate Research Objectives

The intermediate objectives of this study are to determine the degree to which patterns of Japanese knotweed invasion correspond to hydrologic alteration across a flooding gradient in the Delaware and Skagit River Watersheds in the mid-Atlantic and Pacific-Northwest regions of the United States. The Delaware River Watershed is an excellent model system for this research because it has severe infestations of Japanese knotweed (DRIPP 2004; personal observation), it has tributaries which vary in degree of hydrologic alteration, and it has a suite of USGS gauging stations (both above and below dams) which provide the long-term data needed to assess hydrologic alteration. The large, storage reservoirs in the upper tributaries of the Delaware River provide the water supply for New York City. Because the dams are managed for different purposes (some for continuous water supply, and some as back-up storage and flood control structures), the tributaries vary substantially in their degree of hydrologic alteration. A greater understanding of the impact of hydrologic alteration on Japanese knotweed invasion could be incorporated into ongoing efforts to better manage flow regime in the Upper Delaware River Watershed.

Like the Delaware, the Skagit has tributaries which vary in degree of hydrologic alteration, as well as USGS gauging stations (both above and below dams) which provide the long-term data needed to assess hydrologic alteration. The natural flow regime in the Skagit Watershed is characterized by winter rain events and predictable seasonal flooding, typical of the PNW but unlike the generally steady annual rainfall that occurs in the mid-Atlantic (Poff and Ward 1989). Before damming, the highest magnitude flows generally occurred from April to July. The effect of large storage dams above the Newhalem, WA USGS gauge has been an increase in overall base flow, and decrease in high magnitude spring flood events. The decrease in high magnitude floods could result in an increase in the size and dominance of large, clonal Japanese knotweed plants in the portion of the riparian zone not inundated by the elevated base flows.

Long-term Research Objectives

The long-term goal of this research is to devise flow management strategies for rivers affected by dams that promote native species diversity while limiting exotic species invasion across broad scales in riparian plant communities. These management strategies could then be incorporated into dam re-operations to optimize the ecological integrity of riparian zones. An understanding of the relationship between flow regime, native plant community composition, and exotic species invasion for a wide range of river systems and invasive species will be necessary to achieve this goal. This increased understanding would be achieved by addressing the following questions:

Does hydrologic alteration increase overall invasion?

Hydrologic alteration may increase opportunities for invasive species by causing a decline in the native community or by creating new sites suitable for exotics. Alternatively, hydrologic alteration may have net negative effects for all members of the system, including exotic species. The extent to which each of these is true may depend on the river system and the species pool.

How does hydrologic alteration affect Japanese knotweed (or other specific exotic plant species)?

If Japanese knotweed is a generalist species with the ability to survive in a broader range of habitats and flow regimes as compared to many key native species of riparian systems such as alder, willow, cottonwood, or sycamore, it could establish in altered habitats that native plants cannot tolerate. This could be true for a wide range of invasive species with 'generalist' characteristics. Alternately, like many key native species of riparian systems, Japanese knotweed may be a specialist, with specific habitat requirements set by variations in light, soil fertility, and flow regime. In some cases, hydrologic alteration may create 'new' habitats that are more favorable to Japanese knotweed than to other species. Another alternative is that Japanese knotweed may be filling a previously empty niche. Each of these alternative hypotheses may be true at different stages of the Japanese knotweed life cycle (see Figure 1), and has different implications for the ecological impacts and management of Japanese knotweed.

In addition to hydrologic alteration, there are many factors (such as past plantings of Japanese knotweed as ornamental species and past land use) within watersheds that make it difficult to distinguish the effect of flow regime on Japanese knotweed. A major goal of this study will be to tease apart the effects of hydrologic regime from these other factors at different stages in Japanese knotweed life history.

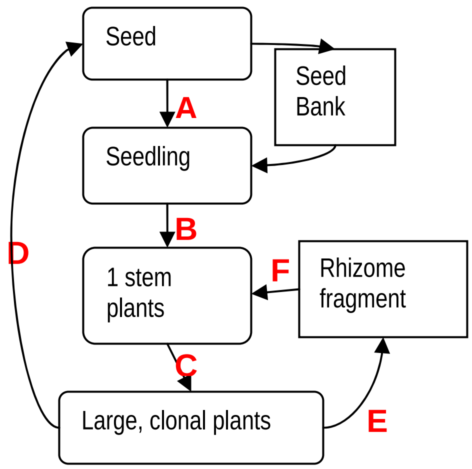

Figure 1. Japanese knotweed life cycle stages and hypothesized relationship to hydrologic alteration

A. Extended low flow periods in spring create new habitat for seed germination
B. Long duration floods in spring reduce seedling survivorship.
C/D. High magnitude/intense floods during growing season prevent Japanese knotweed dominance by damaging plants
E. High magnitude/intense floods disperse plants via rhizome fragments.
F. Rhizome fragment establishment decreased by long duration, growing season floods.

Methods

We sampled in the Skagit watershed in Western Washington and the Upper Delaware watershed in Upstate New York, both of which are influenced by damming, to determine patterns in exotic species invasion related to hydrologic alteration and a suite of other factors known to affect exotic species invasion (hydrologic regime, land use history, soil properties, geomorphic position).

Study Area

During the last week of July, 2005, Japanese knotweed was sampled on two 10 mile reaches within the Skagit Watershed: the Skagit River from Marblemount its intersection with the Sauk, and the Sauk River (the 10 miles above its intersection with the Skagit). The Sauk River is free flowing while the Skagit is affected by the Diablo Dam which results in higher base flow levels but lower peak flow levels than historically occurred.

We sampled the Upper Delaware River during the last two weeks of August, 2005, including its main stem near Hankins and Callicoon, NY, and several tributaries including the East Branch Upper Delaware, West Branch Upper Delaware, and Beaverkill. Where dams were present, we sampled above and below the dams. Table 1 shows the number of reaches sampled for each river segment.

The East Branch of the Delaware is impounded Pepactin Reservoir, which strongly reduces base flow during summer months while Cannonsville Reservoir results in elevated base flows on the West Branch of the Delaware. The Beaverkill River is free flowing.

Table 1. River Reaches Sampled.

River Reach	Dam influence?	Approximate Reach length (miles)	Number of reaches sampled
Skagit, Western WA	Yes, Diablo dam	10	1
Sauk, Western WA	None	10	1
East Branch Delaware, NY	Above dam, none	2	1
East Branch Delaware, NY	Yes, Pepactin Reservoir	2	2
West Branch Delaware, NY	Above dam, none	2	2
West Branch Delaware, NY	Yes, Cannonsville Reservoir	2	2
Beaverkill, NY	None	2	2
Mainstem Upper Delaware, NY	Yes, Pepactin and Cannonsville Reservoirs	2	2

Vegetation Survey

We quantified distribution and abundance of Japanese Knotweed along each river reach by marking knotweed locations using a Garmin GPS unit. On the Skagit River, the size (length x width) and vertical distance from the river of each contiguous knotweed patch was recorded. In addition, the geomorphic position where the knotweed was found was categorized as floodplain, bar, or bank. Patches sampled included those visible from the river. Sampling was integrated with sampling data collected by the Nature Conservancy, which is actively controlling Japanese Knotweed within the Skagit watershed.

In the Upper Delaware Watershed, where Japanese knotweed was much more abundant, the river length of each patch was recorded (e.g. the length of river bank covered by each patch). For patches greater than 15 meters long, the beginning and end point on each patch were recorded with the GPS and length was calculated. In each river reach sampled in the Delaware watershed, 2 transects were placed across representative knotweed patches. The transects were oriented perpendicularly to the river. On each transect, we measured changes in the height and width of Japanese knotweed patches with vertical distance to the river.

Data analyses are ongoing. Japanese knotweed locations are being mapped in a GIS framework, and hydrologic regime will be quantified using the Indicators of Hydrologic Alteration (IHA) program (Richter et al. 1996), which calculates a series of metrics using gauging station data that can then be compared across sites (or dammed reaches with reference reaches) or to daily flow data from the same site that predates the alteration event (dam or otherwise).

<u>Preliminary Results</u>

In the Skagit watershed, we recorded 50 knotweed patches on the Sauk River, and 72 on the Skagit. Results from a t-test showed that knotweed was found at a higher average vertical distance from the river on the Sauk (2.1 m) compared to the Skagit River (1.5 m) ($P < 0.001$). Further analysis is needed to determine if this difference is caused by hydrologic alterations due to dams or potentially other factors. There was not a significant difference in knotweed patch size between the two rivers or among geomorphic positions. On both rivers, Japanese knotweed patches were more frequently found on floodplains than in banks or bars (Chisq=12.8, P=0.002;

see Table 2). Generally, there was relatively little Japanese knotweed on the Sauk and Skagit Rivers compared to the Upper Delaware watershed. This may be in part due to the fact that the invasion is only at its initial stages in this region, and also due to the control efforts of The Nature Conservancy. I am continuing to compare my data with that of The Nature Conservancy.

Table 2. Frequency of Japanese Knotweed patches across geomorphic positions in the Sauk and Skagit Rivers.

	Sauk	Skagit	Total
Bar	9	10	19
Bank	3	24	27
Floodplain	38	38	76
Total	50	72	122

In the Delaware River Watershed, Japanese knotweed was common in all reaches sampled, however there were some distinct differences in size and frequency of knotweed patches among reaches. There were smaller, more frequent patches of knotweed on the undammed Beaverkill and upper reaches of the East and West Branches of the Delaware, whereas there were fewer, larger patches on the West Branch and Main stem of the Upper Delaware (see Table 3). This suggests that the natural flow regimes may affect the dispersal of knotweed, and its ability to grow to a large size. The largest patches of knotweed were in reaches affected by damming, particularly in the main stem of the Delaware, where knotweed is extremely dominant (see Figure 1). In these reaches, knotweed has nearly eliminated all other riparian plant species, and is altering erosion patterns along the river banks. Because its roots are not as fibrous as other riparian species (such as grasses), banks with knotweed are frequently undercut and eroded.

Data analyses are ongoing for this portion of the study.

Table 3. Number of Japanese Knotweed patches per sample reach in the Upper Delaware watershed.

River	Above dam reach 1	Above dam reach 2	Below dam reach 1	Below dam reach 2
East Branch Delaware, NY	63	NA	47	16
West Branch Delaware, NY	65	61	27	56
Beaverkill, NY	142	99	NA	NA
Mainstem Upper Delaware, NY	NA	NA	50	33

Figure 1. Japanese knotweed dominating the riparian zone on the mainstem of the Upper Delaware River near Callicoon, New York.

Long-term goal and continued progress of research

Japanese knotweed is clearly a significant problem which has devastating riparian plant communities in the Upper Delaware Watershed. In order to preserve riparian species diversity and even the functioning of riparian communities, a method to prevent Japanese knotweed from dominating riparian zones is needed. By understanding how hydrologic alteration affects knotweed, I hope to develop a method (such as a prescribed hydrologic regime; perhaps more similar to the natural flow regime) that might reduce knotweed dominance.

I am making steady progress in analyzing the results from last summer's research. In addition, I received a $10,000 grant from Eastern Washington University to continue sampling Japanese knotweed in Western Washington and Upstate New York and to conduct a greenhouse experiment assessing the effects of hydrologic alteration on Japanese knotweed growth and survival. My students and I initiated the greenhouse experiment earlier this month, and are planning a busy field season sampling knotweed in additional rivers in Western Washington and continuing to sample in Upstate New York. We plan to sample a broader range of rivers in Western Washington, in part because there was relatively little knotweed in the Skagit Watershed. In addition, I plan to submit an NSF grant this fall for additional support of this research. I would especially like to compare the impacts of knotweed verses native plant species on patterns erosion and sedimentation within riparian areas. Results from this research will be submitted for publication.

Benefits of seed money

The benefits of seed money for my research cannot be understated. Although the funds provided by this seed grant were small, they enabled my students and me to travel across the country where we were able to make contacts with local land managers and scientists (including Ken Bovee, USGS, Su Fanok, TNC, and Don Hamilton, NPS), collect a significant amount of data, and learn firsthand how Japanese knotweed impacts ecosystems in both the Pacific

Northwest and Eastern United States. This research was a significant educational experience for the 3 students that were in part supported by these funds. Also, this grant enabled me to leverage funds from Eastern Washington University to continue this research into 2006, and the data collected has helped me to refine my research ideas and will help significantly in my application for an NSF grant and other grants.

Further assistance in advancing this research

This project would make an excellent graduate thesis, and committed, highly qualified graduate students would really energize this research. Funds to support one or more graduate students dedicated to this project would be extremely useful in advancing this research.

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