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Temporal Macroinvertebrate Community Structure in Leaf Packs from a Stream Dominated by Riparian Japanese Knotweed spp.

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ABSTRACT

Stream macroinvertebrates process inputs of allochthonous detritus as part of energy transfer along the food chain to higher trophic levels. The availability, timing, and suitability of these inputs can affect community composition. This study examined the responses of macroinvertebrate functional feeding groups to the shift in leaf litter composition among native overstory species and Japanese Knotweed spp., an exotic riparian understory dominant. Three naturally-formed leaf packs were haphazardly selected, weekly, using a surber sampler ($0.25m^2$) from 7 October (week 1) to 26 December (week 13), 2011. Sampled leaves and macroinvertebrates were preserved in 70% isopropyl alcohol and later identified in the laboratory. Twenty-eight leaf species were collected, along with 250 macroinvertebrates representing 17 different Families. Five functional macroinvertebrate feeding groups (Collector/Gatherer, Filterer/Collector, Predator, Scraper, and Shredder) were identified from the leaf packs. The dominant overstory trees, American Sycamore (*Platanus occidentalis*), Red Oak (*Quercus rubra*), and Box Elder (*Acer negundo*) and the Knotweed understory were compared with functional feeding groups. No significant functional feeding group preferences for any particular leaf species (native or exotic) existed here. Filterer/Collectors were most numerous over the course of the study followed by Collector/Gatherers, Predators, Scrapers, and Shredders. Shredders, comprising less than 6 % of the total complement, did not peak until the final two weeks of the study. Colonizers appear to be utilizing the leaf packs more as a cover - evidenced by the abundance of Filterer/Collectors and Predators. The shift in functional feeding group sequence here may be the result of low quality of the mixed detritus as a result of high lignin content and the relative paucity of shredders in this stream. Understanding the relationships of alien riparian invasives to stream detritus processing will be important to the management and conservation of all streams.

Keywords: allochthonous detritus; invasive plant

The diversity and stability of forested riparian zones are of critical importance to ecological functioning of low order (1-3) stream ecosystems because they serve as the principal source of allochthonous materials providing energy to sustain higher trophic levels (Petersen and Cummins 1974; Cummins et al. 1989; Dangles et al. 2002). Following the formation of leaf packs on the stream substrate and their subsequent colonization by microbes, macroinvertebrate shredders and collectors process the leaves and facilitate energy and nutrient transfer through the lotic food web (Vannote et al. 1980).

Species composition of leaf litter from riparian plants varies in its energy and nutrient content and the rate of decomposition in aquatic ecosystems. Litter breakdown rates are mediated by leaf chemical composition (including C:N ratios) which varies widely among riparian plants (Baldy et al. 1995; Lecerf et al. 2007; Claeson et al. 2014). Because of their low lignin content, some trees species such as Alder (*Alnus* sp.) and Ash (*Fraxinus* sp.) have higher rates of decay than others, including Oak (*Quercus* sp.) (Lecerf et al. 2007). Thus, the quality of allochthonous detritus inputs can markedly influence stream secondary productivity.

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Riparian areas are particularly susceptible to exotic plant invasions (National Research Council 2002) because their dynamic flow regimes create canopy openings and conduits for opportunistic movement of colonizing species (Beerling 1991; Pyšek and Prach 1994). In many areas of the United States, Japanese Knotweed (*Fallopia japonica*) and Giant Knotweed (*Polygonum sachalinense*) (the complex hereafter referred to as either knotweed) have become a dominant plant in the riparian understory. Knotweed was first introduced into the United States in the late 1800's to help control stream bank erosion (Weston et al. 2005). Its aggressive rhizomal and seed dispersal mechanisms (Weston et al. 2005) along with phytotoxic properties (Moravcová et al. 2011; Dommanget et al. 2014) effectively prohibit the growth and regeneration of other riparian species (Parkinson and Mangold 2010). The presence of Knotweed effectively eliminates the ability of many native riparian plants to disperse, establish, and maintain community diversity (Planty-Tabacchi et al. 1996).

Knotweed monocultures create nearly impenetrable walls during the growing season and expose soils during dormancy, thereby decreasing stream bank stability and potentially increasing soil erosion (Dawson and Holland 1999). Dassonville et al. (2011) report that Knotweed also has the potential to alter critical ecological processes by changing the resident microbial community composition which may in turn affect that of the associated macroinvertebrate functional feeding groups (Allan 2004). Such invasive species may thus alter overall energy transfer networks among trophic levels in headwater streams (Vannote et al. 1980).

Headwater streams comprise about 85% of the 133,575 km of flowing waters in Pennsylvania and therefore provide a significant source of detritus for aquatic microbes and macroinvertebrates from their riparian corridors. Knotweed is now present in most Pennsylvania counties and persists within many riparian corridors; however little information exists as to the amenability of its detritus to use and breakdown by resident macroinvertebrate functional feeding groups.

The objectives of this study were (1) to document the composition of naturally-formed in-stream leaf packs generated from a riparian corridor dominated by an understory of Knotweed and (2) to identify macroinvertebrate functional feeding group colonizers of leaf packs composed of a mix of Knotweed and native flora over time. The data presented here is not intended to infer causality, but rather to describe the leaf type composition and macroinvertebrate functional feeding group colonization of naturally-formed leaf packs.

METHODS

Site Description

Pike Run, a third order adventitious warm-water-alkaline tributary to the Monongahela River located in Washington County, was selected for study. This watershed has a history of landscape alteration including surface mining, agriculture, and most recently, highway construction. These disturbances may have allowed for the initial colonization of the riparian zone by Knotweed about 10-15 years ago. Today, Pike Run's riparian understory is largely dominated by Knotweed (up to 100% in some patches) and a canopy of three dominant tree species: American Sycamore (*Platanus occidentalis*), Red Oak (*Quercus rubra*), and Box Elder (*Acer negundo*). Pike Run is organically enriched and the macroinvertebrate community is dominated by hydropsychid and gammarid Filterer/Collectors and Collector/Gatherers, respectively (W. Kimmel, unpublished data).

Methods of Collection and Identification

Some studies employing constructed leaf-packs have demonstrated that Knotweed differs in its macroinvertebrate colonizers and breakdown rates from those composed of native flora (Dangles et al. 2002; Urgenson 2006; Lecerf et al. 2007) while others report equivocal results (Ludrosky and Kimmel 2003; Braatne et al. 2007). The wide variation of methodologies and protocols used by various authors renders comparisons of existing literature difficult across regional landscapes. Naturally-formed packs, however, are typically composed of a mix of detritus types which change over time.

Utilizing a surber sampler ($0.25m^2$), three naturally-formed leaf packs were haphazardly collected within Pike Run weekly from 7 October (week 1) to 26 December (week 13), 2011 (81 day period) and pooled to form a composite for each site. This approach permitted an area of the same dimension to be sampled during each collection event. Collected leaf packs and associated macroinvertebrates were preserved in 70% isopropyl alcohol and processed in the laboratory. Leaves from each pack were gently washed and identified to the species level using Farrar's (1995) key and enumerated.

Collected macroinvertebrates were sorted, identified to the family level using Merritt et al. (2008), and enumerated. Macroinvertebrate abundance was determined as the total number of organisms collected from the three pooled samples, per week. Macroinvertebrates were assigned to their respective functional feeding groups - Predator, Scraper, Shredder, Filterer/Collector, and Collector/Gatherer, as assigned by the US Environmental Protection Agency (Barbour et al. 1999), the Pennsylvania Department of Environmental Protection (PA DEP 2009), and Merritt et al. (2008).

Data Analysis

Weekly leaf pack collections (n=3) were pooled in order to assess temporal variation. Leaf litter from the most frequently collected riparian tree/herbaceous species were considered in the data analyses. The percent composition of leaf species (i.e., the number of individual leaves of a particular species) was plotted over time to evaluate the relative contribution of each to the total detrital content. Macroinvertebrate functional feeding group response and total abundance were compared to proportional representation of leaf species over time using Spearman's Rank Correlation (p-value <0.05). These relationships were not examined to establish causality, but to assess possible changes in macroinvertebrate functional feeding group composition relative to leaf availability and use.

RESULTS

While leaves from 27 different tree canopy species were collected, three dominated the riparian forest - American Sycamore, Box Elder, and Red Oak (Table 1) and were selected for individual comparison with Knotweed composition. The remainder

Table 1. Summary of leaf species collected in packs. Common names shown in bold were riparian dominants, all others were considered in the category, "other".

Common Name	Scientific Name
Box-Elder	*Acer negundo*
Black Maple	*Acer nigrum*
Sycamore Maple	*Acer pseudoplatanus*
Silver Maple	*Acer saccharinum*
Sugar Maple	*Acer saccharum*
Tree of Heaven	*Ailanthus altissima*
White Birch	*Betula pendula*
Shagbark Hickory	*Carya ovata*
American Beech	*Fagus grandifolia*
Japanese Knotweed	*Fallopia japonica, syn. Polygonum cuspidatum*
White Ash	*Fraxinus americana*
Honey Locust	*Gleditsia triacanthos*
Witch-Hazel	*Hamamelis virginiana*
Tulip Poplar	*Liriodendron tulipifera*
American sycamore	*Platanus occidentalis*
Largetooth Aspen	*Populus grandidentata*
Quaking Aspen	*Populus tremuloides*
Black Cherry	*Prunus serotina*
White Oak	*Quercus alba*
Scarlet Oak	*Quercus coccinea*
Chestnut Oak	*Quercus montana*
Pin Oak	*Quercus palustris*
Red Oak	*Quercus rubra*
Staghorn Sumac	*Rhus typhina*
Smooth Sumac	*Rhus glabra*
Black Willow	*Salix nigra*
American Elm	*Ulmus americana*
English Elm	*Ulmus procera*

were assigned to a collective "Other" category and treated as a single entity for comparison (Table 1). Knotweed was the only riparian understory plant present in collected leaf packs. Over the first four weeks, Knotweed comprised less than 10% of collected packs. By week 5 (4 November, 2011) however, Knotweed comprised >30% of collected leaf packs, peaking in week 7 (11 November,

2011) and then slowly tapering to approximately 20% of the total (Figure 1) for the remainder of the study period. During the 13 week study, Knotweed was the species dominant for four weeks (11 November to 2 December; weeks 6-9) (Figure 1). Knotweed, American Sycamore, and Red Oak increased in proportion over time (Figure 1). American Sycamore ranged from 11 to 54% of detrital composition over the study and remained in almost equal proportions to Knotweed as the study progressed (Figure 1).

Table 2. Macroinvertebrate taxa collected and functional feeding group designations

Family	Functional Feeding Group
Caenidae	Filterer/Collector
Sphaeriidae	Filterer/Collector
Elmidae	Collector/Gatherer
Gammaridae	Collector/Gatherer
Psephenidae	Collector/Gatherer
Calopterygidae	Predator
Hirudinea	Predator
Perlidae	Predator
Philopotamidae	Predator
Rhyacophilidae	Predator
Chironomidae	Scraper
Physidae	Scraper
Planorbidae	Scraper
Polycentropodidae	Scraper
Limnephilidae	Shredder
Taeniopterygidae	Shredder
Tipulidae	Shredder

A total of 250 individual macroinvertebrates were collected representing 17 different taxa (Table 2). Filterer/Collectors were most numerous, followed by Predators, Collector/Gatherers, Scrapers, and Shredders (Figure 2). For the first two weeks, Collector/Gatherers dominated, but were later replaced by Filterer/Collectors. Shredders were rare comprising less than 6% of the total complement; furthermore, they did not appear until week five and peaked at the end of the study (Figure 3). Macroinvertebrate functional feeding groups were not significantly correlated with the type of leaf species ($p > 0.05$); however, macroinvertebrate use (as measured by abundance) declined during periods in which Knotweed was the dominant species in leaf-packs but this relationship was not significant ($p > 0.05$) (Figure 4).

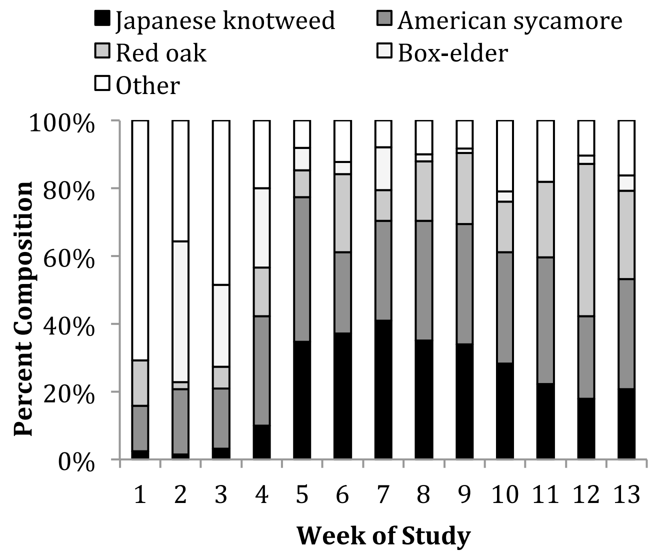


Figure 1. Percent composition by taxon of allochthonous leaf litter in Pike Run pack composites over time. See Table 1 for a list of tree species that comprise the "Other" category.

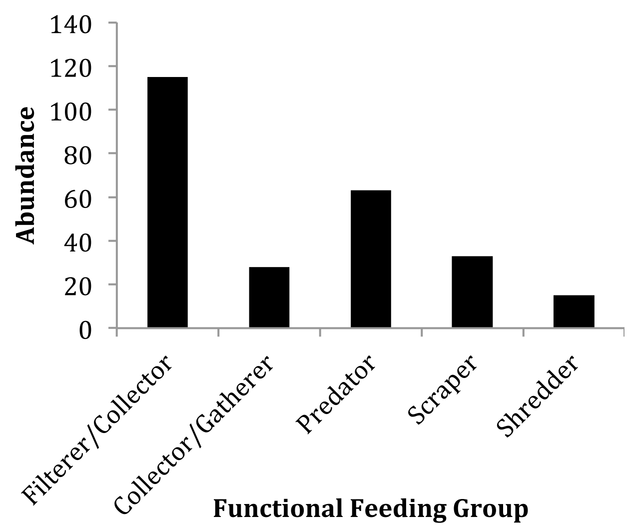


Figure 2. Total abundance of macroinvertebrates, categorized by functional feeding groups.

DISCUSSION

This study documents the presence of resident stream macroinvertebrate colonizers to naturally-formed leaf packs generated by a mix of native overstory and a riparian invasive understory species, Knotweed. Unlike other studies which employed standardized

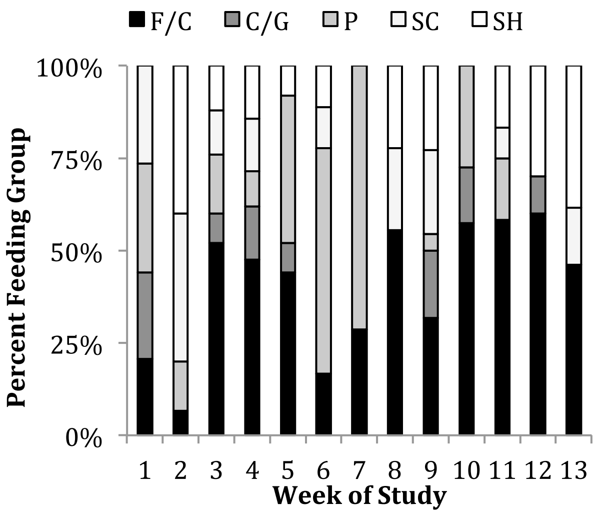


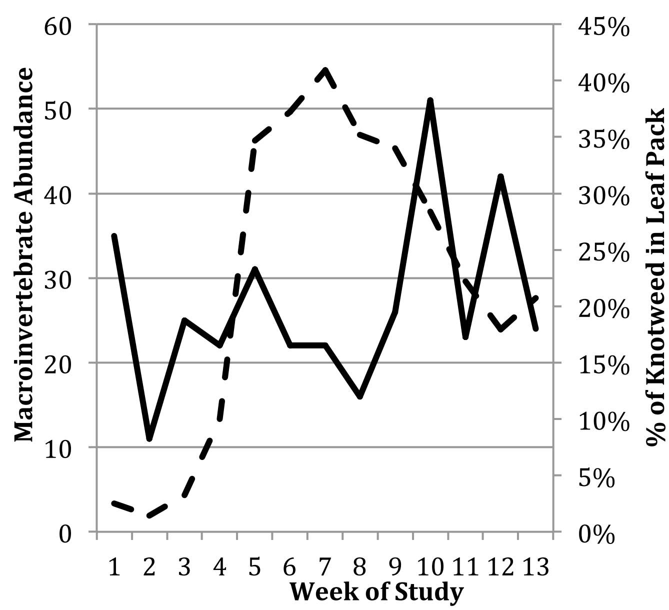
Figure 3. Percent composition of macroinvertebrate functional feeding groups associated with leaf pack composites in Pike Run over time. Acronyms are defined as Filtering/Collector (F/C), Collector/Gatherer (C/G), Predator (P), Scraper (SC), and Shredder (SH).

constructed leaf packs (Ludrosky and Kimmel 2003; Lecerf et al. 2005), this study described the change in detrital recruitment and colonization by examining naturally formed leaf packs. While this sampling design does not offer the control associated with constructed leaf packs, it does afford an opportunity to investigate the temporal dynamics of multi-species leaf packs and their attendant macroinvertebrate colonizers.

Thompson and Townsend (2003) have argued that a co-evolutionary history between aquatic detritus processors and riparian vegetation is not necessary to ensure efficient trophic dynamics in streams. However, other studies (Graça 2001; Richardson et al. 2004; LeRoy et al. 2006) have found macroinvertebrates may be selective of the leaf litter they colonize and suggest the structure of food webs requires long term adjustments within ecosystems following the establishment of invasive plants (Belnap et al. 2005).

Leaf tissues high in lignin content such as those of Oak, Sycamore, and Knotweed exhibit a slower rate of decay than those of low-lignin such as Alder (Gessner and Chauvet 1994; Lecerf 2007; Claeson et al. 2014). Because the leaf litter of invasive Knotweed congeners is considered low quality, it should decompose at a slower rate than leaves of higher quality (Webster and Benfield 1986). Therefore, in areas where Knotweed is dominant, it is available as a food source for extended periods (Graça 2001). However, Dangles et al. (2002) concluded that a sequence of organisms is needed in the processing of Knotweed litter in stream ecosystems. However, in watersheds such as Pike Run, the high lignin content of the major contributors of detritus; Oak, Sycamore, and Knotweed may delay or inhibit microbial and macroinvertebrate colonization which precedes shredding and skeletonization. This may account for the late appearance of Shredders which are also rare here as evidenced by numerous macroinvertebrate samples which are dominated by the Filterer/Collector and Collector/Gatherer functional feeding groups (W. Kimmel, unpublished data).

Filterer/Collectors, in particular caenid mayflies, were the dominant functional feeding group throughout much of the study likely utilizing the leaf packs as cover and providing forage for Predators which were



also common in the packs. These trends

Figure 4. Weekly total macroinvertebrate abundance (solid line) and percent composition of knotweed (dashed line) in leaf pack composites.

suggest that additions of Knotweed may result in changes in the sequence of functional feeding group colonization. Exotic leaves have shown the ability to alter Shredder composition due to poor quality leaf material and the efficiency with which this guild exploits and consumes a low quality resource (Cummins et al. 1989; Findlay and Arsuffi 2006).

Ludrosky and Kimmel (2003) examined macroinvertebrate colonization of constructed leaf packs in the same stream studied here. Leaf packs were constructed with Red Maple (*Acer rubrum*) and Knotweed and deployed for a 42-day period. At the conclusion of this study, packs were evaluated for the percent weight loss of leaves and corresponding macroinvertebrate colonization. They reported that both Knotweed and Red Maple packs contained similar dominant macroinvertebrate taxa: Gastropod Scrapers, *Fossoria* and *Physella* species (Ludrosky and Kimmel 2003). By contrast, Scrapers were observed only once during week five of the present study. While the two studies differ in the identity of leaf-pack dominants, both reveal little activity by Shredders, a likely consequence of poor detrital quality and a paucity of members of this functional feeding group.

Conclusion

Originally introduced to curb soil erosion (Weston et al. 2005), Knotweed can efficiently stabilize stream banks. However, its presence as a dominant riparian species has important ecological implications as to its suitability to provide allochthonous carbon to aquatic systems. Because many streams in southwestern Pennsylvania have become overrun with monocultures of this species, the potential now exists for this exotic plant to shift ecosystem dynamics, from microbial to macroinvertebrate colonization.

The River Continuum Concept (Vannote et al. 1980) offers a conceptual framework of pathways for energy and nutrient transfer within a stream/river network. However, in light of the fact that riparian areas are now home to many exotic invasive plant species, attention must be given to understanding their impacts on stream detritus processing and energy transfer.

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