The Effects of Savanna Restoration on Ant Communities

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Abstract

Temperate savannas are an important ecotone between prairies and forests. I studied the effects of savanna restoration on ant communities because ants are important ecosystem engineers. Specifically, I studied the most effective way to sample ants in temperate savannas, and how savanna restoration efforts influence ant species communities. I sampled 21 sites using pitfall traps and leaf litter sifting methods. Pitfall traps were more efficient due to their ability to capture a higher number of species rapidly with less effort. Ant species richness increased with age of restoration. Myrmica punctiventris is a potential indicator of high quality savanna habitats because it was collected in eight of the higher quality sites by one trapping method (pitfalls). Temnothorax schaumii is a common species in sites that had been restored 7-15 years and may also be a potential indicator of restoration success. These results may help restoration managers focus their efforts and resources.

Introduction: Background and history of North American temperate savannas and ants

North American Temperate Savannas:

Savannas in North America are a unique and once common ecotone lying between the open prairies and closed canopy forests (Cavender-Bares & Reich, 2012; Maloney, 1997; Peterson & Reich, 2001). Characterized by a continuous layer of grasses with patches of trees and shrubs (Peterson & Reich, 2001), savannas historically occurred in areas with a high frequency of fire. Today savannas are rare and often only found in soil that was considered too poor for agricultural use (Peterson & Reich, 2001; Houdeshell et al., 2011).

The savanna ecotone was once one of the most prevalent features on Midwestern prairies and is believed to be developed by periodic burns originating from natural fires and those set by Native Americans (Maloney, 1997). After hundreds of years of fires, from natural or human sources, grasslands and savannas are able to take over what was traditionally a forest (Denavan, 1992). Lightning and naturally occurring fires also have the same effect on the ecosystem as Native American fires (Denavan, 1992). However, it would have been unlikely that these natural fires caused all savannas, because of the time it would take for the conversion from closed forests to the more open savanna and grasslands (Denavan, 1992). Without the burning done by Native Americans in the Midwest for the past 5,000 years, savannas would have been naturally converted to closed canopy forests (Denavan, 1992).

Once the European agricultural practices of clearing and burning were brought to the Midwest, pristine savanna ecotones became degraded (Denavan, 1992). The European agricultural practices caused a conversion from a more open savanna ecotone system to a closed canopy forest system (Denavan, 1992). The European explorers and settlers failed to keep detailed records of the Native American practices; therefore, we can only make educated guesses as to what maintained the savanna ecotone (Denavan, 1992).

The lack of fire in these new cropland and farmland ecosystems, started by the Europeans, caused a selection against fire-tolerant species and in some cases has allowed a return from the savanna ecotone to the closed-canopy forests (Cavender-Bares & Reich 2012; Maloney, 1997, Peterson & Reich, 2001). Another reason fires have been suppressed is due to the grazing of livestock on savannas (Van Langeuelde et al., 2003). Overgrazing by livestock has led to a decrease in woody plant life, such as trees, and consequently decreased the fire intensity to the ecosystem (Van Langeuelde et al., 2003). This change in environmental conditions had allowed for the introduction of non-native plants into savannas, which would not normally be able to survive (Peterson & Reich, 2001).

Often these non-native plants have characteristics that allow them to out-compete native species, therefore causing the need for their removal (Maloney, 1997; Van Langeuelde et al., 2003). The common buckthorn, Rhamnus cathartica, has become a common invasive species to Illinois savannas since in the 1970s (Apfelbaum & Haney, 1989). Native to Europe and Western Asia, the common buckthorn was brought to North America sometime in the 1800s as a landscaping plant and has since grown out of control (Knight et al., 2007). It is able to survive in a variety of habitats, from drought prone to flooded areas. Common buckthorn leads to dense shading near the ground, and the elimination of native species (Apfelbaum & Haney, 1991; Knight et al., 2007). The ability of common buckthorn to produce leaves that bud earlier and last longer than the native plant species is a cause for dense ground-shading (Knight et al., 2007). The increased shading of the common buckthorn allows it to block sunlight to the savanna grasses; changing the habitat and reducing the amount of fuel available to the burns, which are necessary to keep the savanna ecotone present (Apfelbaum & Haney, 1991). Additionally, the common buckthorn possesses a chemical compound with the ability to deter insects and mammals from feasting on the plant, thereby altering decomposition and the nitrogen and carbon cycling in an ecosystem changing the structure of the savanna ground cover (Knight et al., 2007). Lonicera maackii, another invasive species, produces litter that decomposes at a higher rate than native plants (Poulette & Arthur, 2012). The faster decomposition results in higher nitrogen levels in the soil and a reduced level of leaf litter in the ecosystem (Poulette & Arthur, 2012). The loss in leaf litter then leads to a loss of fuel available to ecosystem sustaining fires (Poulette & Arthur, 2012).

The periodic fires that are needed to continually maintain savannas are also needed to maintain a suitable habitat for the red-headed woodpecker (Melanerpes erythrocephalus), a threatened Illinois savanna species (Brawn, 2006). Studies have shown that the red-headed woodpecker will not nest in the closed canopy forest habitats (Brawn, 2006). The woodpecker does not necessarily need an extensive savanna habitat to be successful and will usually do well with smaller restored savannas (Brawn, 2006).

Methods Used to Restore Savannas:

Although little is known about the specifics that go into restoring a savanna site, it is known that to preserve the savanna ecotone and the species that rely on it, each savanna needs to be recognized as its own ecosystem and therefore needs a tailored plan specific to the site's exact demands (Dettman et al.,

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2009; Brudvig & Asbjornsen, 2007). Often savanna restoration work is focused on returning burning practices to an ecosystem; however, the non-savanna invasive species are often resilient to fire (Brudvig & Asbjornsen, 2007). The restoration process is not instantaneous, and should begin with the removal of invasive brush and trees not part of a fire-dependent system with the use of chainsaws, bush-cutters, chemical sprays, or burning (Dettmann et al., 2009; Nielson et al., 2003; Brudvig & Asbjornsen, 2009).

Removal of woody and brush plant material, when chopped down and burned offsite, causes an increase in understory vegetation but an overall decrease in leaf litter, changing the amount of fuel available to a burn (Brudvig & Asbjornsen, 2007). However, if left alone after reducing overall tree density by removing woody plants, shrubs, and saplings will return to pre-removal levels within 2-3 years (Brudvig & Asbjornsen, 2007). The combination of the removal of plants and a prescribed burn to a savanna may raise the mortality of non-savanna species (Brudvig & Asbjornsen, 2007). While removal of woody plant material should be done to open the understory of the savanna to native species, re-seeding of naturally occurring species should occur directly after the plant removal to allow the species to take hold in the newly opened habitat (Brundvig & Absjornsen, 2009).

Tree and bush removal is often accompanied by burning (Hartung & Brawn, 2005). By leaving an open canopy and reducing understory plant species, burning changes the plant structure and composition leading to a larger population of shade-intolerant species (Hartung & Brawn, 2005). These habitats have been shown to support native species more productively than the non-restored sites (Hartung & Brawn, 2005). Burning and the removal of trees from the savanna ecosystem change the structure and help to give the site more savanna characteristics (Nielson et al., 2003). Within 1-5 years after timber removal and burn, between 52-78 ground layer plant species had returned to the savanna (Nielson et al., 2003). However, if a site has been more of a closed canopy forest for 50 years or more and/or the fire is not very intense, the restoration efforts may not take hold in the sites; therefore, a method to monitor these changes is needed. Plant introduction and removal is critical during the first few years of restoration and the sites need to be monitored (Peterson & Reich, 2001). Although the removal of the woody plants causes an opening in the ground cover, the invasive species may not be fully eliminated (Brudvig & Absjornsen, 2009).

Therefore, an indicator species is often used to monitor a restoration sites' development (Noss, 1990). An indicator species needs to be commonly found in the environment, have an impact on the ecosystem, be easy to collect, and reproduce quickly so there is not a significant decrease in either the population or the species (Noss, 1990). Ants are a potential source of indicator species because they have large populations, permanent-nesting habits, and can be found in almost all terrestrial habitats and niches (Talbott, 1934). Most importantly ants are sensitive to the environment, with the health of their surrounding environment dictating the health of the colony overall (Talbott, 1934). Knowing the roles that ants play in the ecosystem is important because the effects that restoration has on the species may have a further role in how the ecosystem responds. Ants, among other things, assist in seed dispersal and nutrient cycling in an ecosystem (Philpott et al., 2010).

Ants:

There are over 12,000 described species of ants, occupying nearly all terrestrial ecosystems (Ward, 2007). Ants are true insects nested within the order Hymenoptera, which also includes the bees and wasps (Ward, 2007). In Illinois savannas, common ant genera include Formica, Lasius, and Myrmica (Newman & Wolff, 1990). Ants in savannas, just as in other ecosystems, are important in the movement and enrichment of soil (Newman & Wolff, 1990; Trager, 1998).

There are three categories of growth for a colony of ants (Hölldobler & Wilson, 1990). The youngest being the founding stage, where the nuptial flight of the virgin queens and males takes place (Hölldobler & Wilson, 1990). The first sets of workers are born shortly after the colony is established (Hölldobler & Wilson, 1990). From the founding stage, the queen and the workers move into the process of colony growth (Hölldobler & Wilson, 1990). In the final stage, the reproductive stage, the colony focuses on creating new virgin queens (Hölldobler & Wilson, 1990). All known ant species are perennial, meaning that the colony is releasing these reproductive males and virgin queens to take part in the nuptial flight once a year (Hölldobler & Wilson, 1990).

These newly fledged queens will create their own colonies building new nests that can be found in something as small as an acorn, to something as large as a tree trunk, or as unique as attaching leaves together and living in the canopy of a tree (Lach et al., 2010). Some species are considered cavity-nesters, building their colony nests in small nuts (such as acorns) and twigs (Houdeshell et al., 2011). The most common nests in temperate environments are dug into the leaf litter and soil (Lach et al., 2010). The habitat and nutrition available in the surrounding ecosystem play a role in the health of the colony (Lach et al., 2010).

By building a leaf litter nest, the ground dwelling ants affect the health of the ecosystem with the relocation of nutrients and aeration of the soil (Trager, 1998). The external mounds left behind when an ant colony dies out will be taken over by other small animals (Trager, 1998). Mounds are often an ideal area for plants to take root, due to the higher concentrations of nitrogen and phosphorus held within the mound soil as compared to the surrounding soil content (Berg-Binder & Suarez, 2012; Whitford, 2002). Dead ants and their waste help to enrich the soil allowing for the fertilization and success of young plants (Trager, 1998). Other genera, Formica and Aphenogaster, have been shown to be secondary dispersers of native and invasive seeds when dropped on the ground (Formica species) (Berg-Binder & Suarez, 2012). By collecting and transporting these plant seeds, ants are also reducing parent-seedling competitions, furthering plant species survival (Parr et al., 2007). Ants could be important as an indicator species due to their presence in terrestrial ecosystems, population size, and impact on their environments (Ellison et al., 2007).

General Collection Methods:

Since ants play such important roles in North American temperate savanna ecotones, the proper method of collection is important to know for any given ecosystem. The common methods used to collect ants include: pitfall traps, leaf litter collection, baiting, insecticide, and hand collection (Romero & Jaffe, 1989; Ellison et al., 2007). Hand collection requires the most expertise as one is often just looking for the species as they are walking through the site (Underwood & Fisher, 2006). However, hand collection has been shown to obtain a larger collection of ant species per site when compared to other methods of collection (Ellison et al., 2007; Underwood & Fisher, 2006). Baiting with either tuna or cookies requires the bait to be crushed or broken up and left on a card; then after a few time intervals, the ants present are collected by hand (Ellison et al., 2007). This use of baits has been shown to collect the more aggressive ant species, and exclude the more cryptic ones (Ellison et al., 2007).

More commonly in savannas leaf litter samples and pitfall traps are used (Underwood & Fisher, 2006). Leaf litter samples require a collection; often equaling one meter squared, of topsoil, leaf litter, twigs and plant material (Underwood & Fisher, 2006). Once collected the materials are chopped and sieved in the field before being hung in winkler extraction bags to collect the different insects that were present (Underwood & Fisher, 2006). The second method of collection, pitfall traps, consists of plastic containers placed flush in the ground over the sampling area (Underwood & Fisher, 2006). These cups are left open for a predetermined number of days to allow primarily for the collection of insects. Although, some small mammals and amphibians have also been collected (Ellison et al., 2007). Pitfall traps are often considered an effective and inexpensive method to capture surface foraging species (Underwood & Fisher, 2006). In some studies, pitfall and leaf litter sampling have accumulated the same number of species (Underwood & Fisher, 2006; Ellison et al., 2007). Both collection methods are also easy to transport and complete, while the actual sorting and identification of species has been shown to be more labor intensive (Ellison et al., 2007).

Effect of Restoration on Ants:

Restoration processes have shown an impact on the type of ants found in different ecosystems (Philpott et al., 2010). Some practices have been shown to have negative effects on ant diversity, whereas others have shown to be positive (Underwood & Fisher, 2006). Fire, a commonly used savanna restoration technique, can have a negative effect on arboreal and cryptic leaf litter species (Philpott et al., 2010). Burns cause the density of leaf litter and potential nesting sites to dwindle for some time post-fire (Houdeshell et al., 2011). In the short term, post-burn, leaf litter, and twig nesting ant species populations decrease with a shift to Camponoutus, Aphenogaster and Formica species (Trager, 1998). Over time, the leaf litter and twig nesting ant species will bounce back and population levels will increase post burn (Trager, 1998). Agricultural practices that have plagued the savanna ecosystems have also been shown to reduce the diversity in ant taxa present (Philpott et al., 2010). In Australia, the practice of clearing land for agriculture has reduced ant species richness both at the genera and species levels (Underwood & Fisher, 2006). Historically in Illinois, approximately 10 genera were found in pasture or agricultural fields (Gregg, 1940). However there is a lack of modern research in temperate savanna and agricultural ecosystems to describe any potential differences from the historical data.

Because ants are able to reflect the change in their environments, and a lack of research is available to the scientific community, I wanted to compare the collection methods of ants in North American temperate savannas and what effects restoration processes in these savannas had on identifying indicator species.

Chapter 1: A comparison of collection methods in North American temperate savannas

Introduction:

Due to their quick reproduction rate, large colony size, commonness, significance to the ecosystem, and ease of collection and identification, ants are a potential indicator species for the savanna ecotone (McGeoch & Gaston, 2000; Parr & Chown, 2001; Van Rensburg et al., 1999). Indicator organisms are important because they can be quickly affected by a changing ecosystem (McGeoch & Gaston, 2000; Parr & Chown, 2001; Van Rensburg et al., 1999). Since multiple sampling methods are available with different levels of success, it is important to know which method is the most efficient for a particular habitat (Romero & Jaffe, 1989).

Some of these different methods include: pitfall traps, leaf litter sifting, hand collections, and baiting (Romero & Jaffe, 1989; Ellison et al., 2007). Baits are biased towards competitive ants, while hand collection requires an expert in ant ecology or biology (Ellison et al., 2007). Restoration land managers need a simple collection method to study the results of their restoration effort and both leaf litter sifting and pitfall sampling, on the other hand, have been found to be simple to complete by non-experts, portable, and inexpensive (Olson, 1991).

There is a relative lack of research done in temperate climates comparing ant collection methods. Previous studies have demonstrated that the leaf litter sifting method, compared to other methods, is more suitable to the tropical wet rainforest or montane forest-grassland habitats (Fisher, 1998; Fisher & Roberston, 2002; Olson, 1991). Leaf litter sifting is believed to be the more efficient method in these forests due to the thicker layer of leaf litter that lines the forest floor (Parr & Chown, 2001). Ecosystems with a thicker layer of leaf litter tend to be dominated by leaf litter nesting ants (Parr & Chown, 2001). Leaf litter sifting is often considered to be a snapshot of the ecosystem since it only allows for the collection of whatever organisms are present in the sampling area at that exact time (Ivanov & Keiper, 2009). Pitfall traps, on the other hand, allow for continuous, day and night, sampling (Parr & Chown, 2001). This is important because during the hot hours of the day many ants are less active and therefore less likely to be sampled (Anderson, 1991; Paar & Chown, 2001). Pitfall traps have been found to be more effective than other collection methods in South African tropical savannas, and in Madagascar's dry forests (Anderson, 1991; Fisher, 1998; Parr & Chown, 2001). However, the understudied temperate savanna ecotones differ from these tropical systems in that they have a less dense leaf litter cover (Anderson, 1991; Fisher, 1998; Parr & Chown, 2001).

Due to differences between tropical rainforest and temperate savannas, further research in other ecosystems' collection methods is needed. Tropical savannas and temperate forests are closer to the temperate savanna ecotone and therefore may give a better idea to which collection method would suit temperate savannas (Parr & Chown, 2001; Ivanov & Kiper, 2009; Romero & Jaffe, 1989). In tropical savannas pitfalls were more efficient for collecting ants (Parr & Chown, 2001; Romero and Jaffe 1989), while in the temperate forest leaf litter sifting was more efficient (Ivanov & Kiper, 2009). The temperate savanna ecotones are an understudied and rapidly disappearing ecotone between the prairies and deciduous forests in northern Illinois. They tend to have less dense leaf litter cover and more variable weather than the tropical savannas (Brudvig & Asbjorsen, 2007; Parr & Chown, 2001).

While different trapping methodologies have been compared in tropical and sub-tropical savanna ecotones, no work has been done in temperate savannas. I hypothesized that pitfall trapping rather than leaf litter sifting would be a more efficient method in the temperate savannas, due to the lower volume of leaf litter cover and success of pitfall traps in sub-tropical savannas (Romero & Jaffee, 1989). In particular, I wanted to know if the overall amount of work that went into each method was different, and if there was a bias towards which species were captured in the different sampling methods.

Chapter 2: The Effects of restoration on ant species richness and the possibility of an indicator species for healthy temperate savannas in North America

Introduction:

In order to monitor the savannas' restoration progress, an indicator species is needed (Underwood & Fisher, 2006). The use of an indicator species allows ecologists monitoring a site to quickly assess the effect that a treatment is having on the habitat in question. Ants are an organism that fit the criteria of being an indicator species by being able to be quickly identified, have large colony size, reproduce quickly, and they are significant to the ecosystem making them a potential source of indicator species for the environment (McGeoch & Gaston, 2000; Parr & Chown, 2001; Van Rensburg et al., 1999).

The ages of restored areas can potentially have an effect on the amount of leaf litter present, and the number and variety of ant species present (Maloney, 1997). However arthropods generally have shown a negative response to increased burning frequency in prairie, oak savanna, and oak woodland in Minnesota, eventually returning to normal levels after approximately one year (Coleman & Rieske, 2006; Siemann et al., 1987).

Historically in Illinois savanna-like ecotones there have been an estimated 10-13 genera of ants present (Gregg, 1940; Talbott, 1934). This is estimated because the actual savanna ecotone was not included in the original research of the area; therefore, a hypothesis was made through descriptions of pasture, forest margin, and meadow habitats (Gregg, 1940; Talbott, 1934). Common ant genera include Aphaenogaster, Ponera, Pheidole, Monomrium, Myrmica, Leptothorax (now Temnothorax), Iridomyrmex (now Forelius), Camponotus, Lasius, Formica, Prenolopis, Crematogaster, Solenopis, Tapinoma, and Brachymermex (Gregg, 1940; Talbott, 1934). However, restoration efforts may have an effect on the species richness of the site, depending on the methods used. Conservation practices in McHenry County include controlled burns, underbrush removal, selective and non-selective herbicides for removal of invasive species of plants, and reseeding of the area with native savanna species (Maloney, 1997).

I hypothesized that by documenting the effect that restoration methods had on species richness, I would be able to see greater species richness in older restoration sites. In particular, I wanted to know if there would be an indicator species that correlated with age of restoration, due to habitat changes and the role that that particular species plays in the surrounding environment.

Results

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