Title: The Effects of Removing Buckthorn on a Bog in Western Minnesota

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Abstract:

Bogs are wetland habitats that provide a variety of ecosystem services, have interesting soil properties, and support a variety of species which makes these habitats different from other habitats. However, bogs are susceptible to destruction by anthropogenic activity and to invasive species. Buckthorn, an invasive species to the Great Lakes region, has thrived in areas around bogs, although this has not been well-studied. I plan to investigate the effect of removing buckthorn on bog health at a bog in Western Minnesota. Bog health will be determined by assessing the success of native vegetation, the macroinvertebrate community, soil quality, and exotic earthworm co-facilitation. Buckthorn will be removed in 5 plots around the edges of a bog and buckthorn will remain in 5 plots. I predict that there will be more diverse and abundant native vegetation, a more diverse and abundant invertebrate community, higher quality soil, and fewer exotic earthworms in plots where buckthorn has been removed.

Introduction (Background and Significance):

Bogs are unique wetland ecosystems that provide a variety of ecosystem processes, have interesting soil properties, and support a variety of species. The formation of bogs is dependent on the geology of the landscape. Bogs in the Great Lakes region are the result of glaciation and deglaciation activity during the Pleistocene, in which the glaciers left large pits that are now lakes or ponds (Larsen 1982). These pits develop into bogs when peat, a combination of *Sphagnum* moss, branches, and other organic material, accumulates over the water source (Damman et al 1987). Accumulation only occurs in areas of higher productivity than decay (Damman et al 1987). Productivity occurs when MOB, methane-oxidizing bacteria, has a mutualistic relationship with the *Sphagnum* moss accumulating in the forming bog (Putkinen et al

2014). The development of bogs sets up the soil and water properties that make them different from other habitats.

Bogs have very distinct water and soil properties that vary from other ecosystems. Peat contains large amounts of un-decayed material (Larsen 1982), causing the soil to be very acidic, be nutrient-poor, carry out anaerobic processes, have low temperatures, and have high humidity (Opelt et al 2007). Also, it takes much longer for organic matter to decompose in bogs than in other habitats (Damman et al 1987). Water only reaches vegetation in bogs by precipitation and not by runoff, which keeps them waterlogged, since bogs are relatively small, isolated “islands” (Damman et al 1987). The ecosystem services from the water and soil in a bog are important to the flora and fauna that live there.

A bog habitat supports a variety of different and rare species because vegetation that grows in bogs can only root in peat or un-decayed material (Damman et al 1987). The vegetation in bogs does not receive many nutrients, so the bog must to be able to support vegetation that can survive without nutrients or with limited soil nutrients. Bogs support the growth of a variety of different vegetation, including orchids and carnivorous plants. A diverse variety of microorganisms in the soil exist that are specific to a particular species of plant, which help the plant succeed (Opelt et al 2007). A variety of insect species are also supported in bogs like bees, moths, dragonflies, and damselflies which are important for pollinating the flowering plants (Damman et al 1987). Bogs also support arthropods, like millipedes and pillbugs, which are important prey for carnivorous plants (Thum 1986). Many of the species, like the orchids, that inhabit bogs are rare and endangered, so the need to protect these species is great (Damman et al 1987).

Anthropogenic activity and other stressors are causing the amount of bogs to decline and the size to decrease. Habitat destruction is likely to decrease the genetic diversity of a species, as shown in a study about beetles. In a variety of small, destroyed bog habitats, a species of beetles was studied for genetic diversity, and the results showed that in larger, high quality bogs, this species of beetle had more genetic

diversity than in smaller, low quality bogs (Drees et al 2011). A similar study examined the health of an endangered ant species that are only located in a bog in the Netherlands. When the quality of the soil was better and the size of the bog was larger, the population size of the Black Bog Ant was larger (Mabelis et al 2005). Quality of bogs refers to the amount of nutrients, acidity, temperature, and amount of precipitation in the bog. Lower acidity, lower nutrients, constant temperatures, and constant amounts of precipitation are necessary for bog habitats to thrive because flora and fauna are sensitive to changes in bog quality (Damman et al 1987, Drees et al 2011). Destruction poses a threat to bogs and gives the necessity to protect them.

The bogs that remain are also susceptible to invasive species. Buckthorn is a plant known to be invasive to forests and wetlands of the Great Lakes region. The plant is native to Europe and Asia, but has established communities in the Midwest by means of anthropogenic activity and has invaded a variety of habitats including bogs. This invasive plant is a tall shrub with glossy green leaves and creamy green flowers (Minnesota DNR 2013). Buckthorn has an advantage over native plants because it can grow in both shady and open conditions that get direct sunlight (Knight et al 2007). Seeds of *Rhamnus cathartica* and *Rhamnus frangula*, both species of invasive buckthorn, are dispersed by birds, which allows the plants to establish new populations. Once the plants establish these new populations, they grow rapidly and reproduce every year (Knight et al 2007). The rapid growth and reproduction, along with the wide range of buckthorn has negative impacts on wildlife in the area of invasion.

Buckthorn has a large impact on wildlife and soil properties in the areas that it invades. Buckthorn is more likely to grow than other shrubs, while also taking the light of smaller, understory plants (Mills et al 2012, Larkin et al 2014). When buckthorn grows, it decreases abundance and diversity of other species that are not *R. cathartica* or *R. frangula*, resulting in a homogenization of biota within a habitat. Not only does buckthorn alter the amount of nitrogen in the soil, but also the amount of carbon that can be stored, contributing to the release of carbon dioxide (Heneghan 2005, Larkin et al 2014). As the abundance of buckthorn increases, insects do not have the resources

they need to survive from other plants that buckthorn has outcompeted. Therefore, insect diversity has the possibility of decreasing, while the abundance of buckthorn will continue to expand.

The alteration in nutrient levels in the soil by buckthorn lower the abundance of arthropods like millipedes and pillbugs, while increasing the abundance of invasive earthworms. This happens because of co-facilitation between buckthorn and earthworms. When the abundance of earthworms is increased, it further alters ecosystem processes and nutrients (Heneghan 2005, Knight et al 2007). Earthworms alter ecosystem processes by decreasing leaf litter, which is important for vegetation and other organisms to root in and survive. Earthworms also decrease the microbial activity in the soil (Madritch et al 2009). This affects the growth of plants that need microorganisms to survive. Removing buckthorn can reduce the negative impacts on native species, may decrease the abundance of earthworms, and restore ecosystem health.

When buckthorn is removed, it has a positive effect on the ecosystem. Buckthorn decreases the pollinator community of bees and butterflies that are dependent on the native species, but in a particular study, the pollinator community returned after a long-term removal of buckthorn (Fiedler et al 2012). Buckthorn removal is important for increasing the diversity of both insects and plants in the ecosystem. Along with the increase in abundance of insect pollinators, removing invasive buckthorn also increases the abundance of native vegetation. In another study, removing buckthorn increased the amount of light available for understory vegetation (Heneghan 2005). When there is more light available, more species of plants are able to grow. Soil processes also change with the removal of buckthorn over time. Restoration refers to the removal of buckthorn and returning the composition, structure, and function of an ecosystem to its natural state (Fiedler et al 2012). In a restoration that took place from the 1980s to the 2000s, there was less soil erosion and more carbon storage (Larkin et al 2014). Together, these studies show the importance of removing invasive species, especially buckthorn, from the Great Lakes Region.

The effect of invasive species, especially buckthorn, on bogs is understudied, which makes it a good area of research. Bogs serve a large amount of ecosystem services, but little research has been done on the consequences of invasive species in bogs (Mills et al 2012). It is important to focus on the effect buckthorn has on other plants and the effect it has on insects, along with thinking about the needed conservation efforts to keep bog communities healthy. This study will address the effect of *Rhamnus cathartica* and *Rhamnus frangula* and its removal on natural vegetation and soil properties like temperature, humidity, pH, and litter. This study will also examine the co-facilitation between buckthorn and exotic earthworms in a bog.

Goals of Research and Expected Outcomes:

I will be examining the effects of removing buckthorn on a bog in Western Minnesota. I have four specific aims that I would like to accomplish before the end of the summer. First, I would like to examine the effects of removing buckthorn on native plant populations. I will assess percent cover and survey the vegetation in plots on the edge of a bog where buckthorn has been removed and where it has not been removed. This will be an effort to determine whether plants grow better with or without competition from buckthorn. I predict that there will be a greater abundance and diversity of native plants when buckthorn has been removed.

Second, I will be examining the effects of removing buckthorn on invertebrate communities. Using the plots from the first aim, I will collect litter from each plot and assess the number and diversity of macroinvertebrates. This will be an effort to determine whether invertebrates prefer buckthorn or areas without it. I would expect to find a larger invertebrate community in plots where buckthorn has been removed.

Third, I will examine the effects of removing buckthorn on the soil and microclimate. Using the same plots as mentioned previously, I will measure litter mass, take the soil pH, assess canopy cover, and measure temperature and humidity. This is attempt to determine whether or not abiotic conditions are altered when buckthorn is

removed. I predict that there will be a lower soil pH, larger amount of litter, lower temperature, and higher humidity in plots where buckthorn has been removed.

Last, I will be examining the co-facilitation between earthworms and buckthorn. Using the same plots as mentioned previously, I will identify and count exotic earthworms. This is an effort to determine if earthworm density is dependent on the presence of buckthorn. I predict that there will be fewer earthworms in plots where buckthorn has been removed.

Research Design and Methods:

At the beginning of the summer, I will set up 10 plots total around the edge of a bog in Kensington, Minnesota; 5 of each treatment, and 5 pairs with each treatment that will be assigned randomly. Every plot will measure 10 m by 10 m, plots within the pair will be spaced 5 m apart, and pairs will be spaced 20 m apart. In the center of each plot, a ½ m by ½ m quadrant will be set up, that will be used for the tests that will attempt to determine bog health. In one treatment, buckthorn will be removed and in the other treatment, buckthorn will not be removed. Buckthorn will be removed by cutting it as close to the soil surface as possible with loppers or a saw, and treating the stump with herbicide containing concentrated glyphosate.

Before the treatment assignment, I will do preliminary tests on each plot. These initial tests include canopy cover, ground cover, soil pH, earthworm collection, litter weight, and invertebrate collection. Canopy cover will be assessed by taking a picture of the canopy at the level of understory plants and estimating the percentage of trees or shrubs that are blocking available sunlight. Ground cover will be assessed by taking a picture of the understory at the height of about 1 m and estimating the percentage of understory plants in the quadrant. Soil pH will be taken by placing the Kelway Soil pH Meter about 3 cm into the soil for about 30 seconds to get the reading. I will assess earthworm density by using the “hot mustard extraction method” adapted from Lawrence and Bowers (2002). Mustard powder will be added to a gallon jug of water until the color of the mixture is bright yellow. Then the mixture will be poured onto each

quadrant and earthworms will be collected within 5 minutes, then preserved in rubbing alcohol. For litter collection and weight, I will collect all litter from each quadrant and weigh it at a later time, as it will be used to assess the invertebrate community. The collected litter will be placed in a berlese funnel to collect and store all macroinvertebrates in a jar full of rubbing alcohol. The invertebrates will be identified and counted after 24 hours. Data loggers will be placed on the soil surface in the quadrants and left for the summer. This will track changes in humidity and temperature over time. These data will be recorded every five minutes, until the end of the summer.

At the end of the summer, I will repeat the same tests that I did at the beginning of the summer. This is an attempt to see a change over time, while also being in pairs to determine if macroinvertebrates or earthworms prefer plots with buckthorn or without it. I will also do a vegetation survey at the end of the summer to determine if buckthorn changes the composition of plant species on the edge of the bog. This will only be done at the end of the summer because different plants will be flowering then as opposed to the beginning of the summer.

Broader Impacts

From my research, I hope to prove that bogs should be protected. Since bogs are susceptible to invasive species, while also supporting a variety of rare and endangered species, my research may be able to show that conservation efforts are necessary in bog habitats.

I also hope that scientists in the future can expand on my work. There is a chance that there may not be an effect on bog health right away. It may take more time than just one summer to see a significant change in bog quality. Therefore, I hope that scientists in the future are interested in the effects of invasive species on bogs and are able to use my data to examine long-term effects, rather than just short-term ones like I am.

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