A Darwinian nightmare for humans: poison hemlock, *Conium maculatum*

Ryan Steven Heighton

Abstract: Of all the invasive species known to humans, poison hemlock, *Conium maculatum*, is certainly among the most successful. This paper investigates why it has had such success, particularly in North America; which has only been colonized by poison hemlock for approximately 200 years. Doing a comparative assessment of peer-reviewed studies regarding the plant and its many ecological and evolutionary traits proved to be an effective way of characterizing the biogeographic nature of the species. The spread of poison hemlock has resulted in innumerable economical and environmental costs; in understanding it, preventative measures could possibly be developed. Its success is largely due to two abilities: the ability to defend itself via lethal poisons, and the ability to colonize disturbed habitats. Colonization is enhanced by seeds which do not germinate until ideal environmental conditions are met. The plant is notably allelopathic, producing chemicals that kill almost anything that feeds on it. Poison hemlock is also a fierce competitor with other plants, with almost every ideally competitive trait having been selected for over the course of its evolution.

INTRODUCTION

Ecology of Poison Hemlock

Poison hemlock, *Conium maculatum*, is a notorious plant. From the days of Ancient Greece and the death of Socrates after drinking a potion of hemlock to the present, poison hemlock (herewithin referred to as hemlock for simplicity's sake) is typically given a negative connotation (Berenbaum and Harrison, 1994). This may or may not be reasonable. Poison hemlock is relatively new to North America, migrating from Europe in the 1800s (Vetter, 2004). *C. maculatum* is native to Europe and the Mediterranean, while its sister species *C. chaerophylloides* originated in southern Africa. *C. maculatum* was originally brought to North America for its aesthetic value as an ornamental plant and was not intended for widespread distribution in the wild. It proved to be an excellent competitor in the wild, however, and quickly became naturalized in the United States and southern parts of Canada (Baskin and Baskin, 1990).

The plant was so successful in spreading itself that it reached the west coast of the United States by the early 1900s, showing its remarkable ability to distribute itself (Hillman, 1997). This is especially impressive considering the vast differences in conditions across the continent and the natural competition that it would have had prior to widespread urbanization. Closely resembling parsley and other common non-toxic plants, the extremely toxic hemlock has certainly been proven to be an ecological challenge for many reasons (Castells *et al.,* 2005).

Preferred Habitat

Poison hemlock is a very persistent plant due to its adaptability and wide environmental tolerance. As a general rule, hemlock can thrive anywhere with adequate moisture, even in very disturbed habitats (Baskin and Baskin, 1990). This gives it a competitive edge over many other species of plants, as many require more desolate areas, while hemlock is able to disperse and thrive in stream and ditch banks, and often flooded areas (Greary and Murphy, 2000). Despite this affinity for moist areas, hemlock can also sustain itself in drier areas (Baskin and Baskin, 1990). As mentioned, this range of tolerance is a valuable asset for the plant when competing on a wide scale with other vegetation.

Background of Invasive Species

The definition of a weed has a very vague and subjective nature. Species are typically classified as noxious weeds if they have detrimentally negative effects on other plants or animals, and sometimes if they are perceived as having low aesthetic value (Richardson *et al.,* 2000; Myers and Bazely, 2003). Most noxious weeds are nonindigenous to their area, a necessary criterion in making them invasive species. Such invaders often drastically alter the natural ecology of an area, potentially causing serious damage. This competition can possibly exclude valuable native species depending on the nature of the invader, which can wreak havoc on natural wildlife (Woods, 1997). Aside from the environmental costs, introduced species can also have drastically negative economic results (Pimentel *et al.,* 2000). An example of such a crop is the bur cucumber, *Sicyos angulatus*, which is notorious for invading and damaging important crops. This is particularly true in Europe where it has had serious economic implications, with a great deal of money being lost in the corn and soybean industry (Larché, 2004). Although not all weeds are invasive species to this extent, the danger of ecological interference makes their study essential.

Investigating Biogeography

The study of biogeography is essentially a combination of ecology and evolution and their relation to the geographical location and distribution patterns of a species (Whittaker *et al.,* 2005). Biogeography deals with the complex relationships between innumerable factors which makes it a very complex pursuit. In the context of invasions, studying biogeography can be essential to taking preventative measures and controlling an undesirable plant species.

Poison hemlock's persistence and success in distribution itself across North America makes it a very interesting species to study from a biogeographical perspective. Many invasive species possess obvious traits that give them the competitive edge when competing with native species (Goodwin *et al.,* 1999; Kolar and Lodge, 2001). Since poison hemlock was able to thrive greatly following introduction to North America, it is likely that it possesses many of these traits, thus allowing it to dominate. Many research papers (Goeden and Ricker, 1982; Baskin and Baskin, 1990; Greary and Murphy, 2000) have investigated what these traits are, and the

overall effect that they have had on poison hemlock's success. Review of such literature should therefore provide insight into the biogeographic nature of the species.

METHODS

In order to explore the biogeography of poison hemlock, widespread analysis of its interactions with the environment was necessary. For this reason, the results of a single narrowly-focused study would have been insufficient. To properly assess the ecological distributions and many interactions of this species, a compilation of information from many studies was necessary to be thorough and eliminate chance results. To this effect, the chosen studies were largely from North America, most specifically in the United States. Many excellent studies regarding different aspects of poison hemlock have been conducted over the last half-century, which is likely a result of its relatively recent introduction (200 years ago) to North America from Europe. The studies were further filtered based on their relevance in exploring the biogeographic nature of poison hemlock, that is, exploring why and how poison hemlock has spread across the United States. This relevance ranges from explorations of seed germination, alkaloid influence, preferred habitats, possible allelopathy, and other interactions with plant and animal species.

RESULTS & DISCUSSION

Seed Germination and Possible Reasons for Persistence

The cornerstone and benchmark study regarding germination ecology of poison hemlock was conducted by Baskin and Baskin (1990). This heavily cited paper paved the way for many introspections and analyses of the traits of poison hemlock that make it such a competitive invader. It was determined that hemlock reproduces strictly via seeds, which typically drop next to the parent plant, and eventually result in dense patches of hemlock (Baskin and Baskin, 1990). However, due to the plant's affinity for water, the seeds often drop into water bodies for dispersal, and are also dispersed by birds and small mammals (Baskin and Baskin, 1988). Most temperate perennial plants have narrow time periods for seed dispersal, typically occurring in a span of a few months following maturation of the flower (Howe and Smallwood, 1982). A majority of these seeds lie dormant for many months, leaving them open for predators to consume before spring when they can germinate (Thompson, 1987). Unlike these plants, hemlock stalks survive winter, accommodating a longer seed dispersal season, between September and February (Baskin and Baskin, 1990). These seeds are able to germinate, sprouting new seedlings, in the harsh winter months while the seeds of other plants are still dormant (Baskin and Baskin, 1990). This extended germination period gives hemlock the edge over other competing plants, as it is able to solidify deep roots before many other species' seeds begin germination. Thus, when the peak germination season comes in early spring, hemlock is able to flourish, while competing plants begin to sprout (Baskin and Baskin, 1990). In addition to this advantage, hemlock seeds are able to lie dormant for up to three years in soil until optimal conditions are met for germination (Baskin and Baskin, 1988).

Another prominent reason for hemlock's success is that it has historically been colonized by remarkably few insects (Goeden and Ricker, 1982). Despite growing in moist areas that provide a haven for insect development, hemlock has built up natural defences that protect it against almost all forms of wildlife, except for a few choice species (Goeden and Ricker, 1982; Berenbaum and Harrison, 1994; Castells and Berenbaum, 2006). This defence comes in the form of secondary metabolites, specifically alkaloids, produced in tissues throughout the hemlock plant (Fairbairn and Challen, 1959; Leete and Olson, 1972; Wittstock and Gershenzon, 2002).

Allelopathy: Toxic Alkaloids

There are eight known alkaloids that hemlock produces, with the primary toxins being coniine and coniceine, piperidine alkaloids in the same chemical group as nicotine (Vetter, 2004). This synergy of toxins makes hemlock particularly potent to any potential predators or parasites, especially since one of the toxins alone could have significant pathogenic effects on other species (Wittstock and Gershenzon, 2002). Of all the toxins, coniine is the most potent; it is a neurotoxin that is virulent to all vertebrates (Vetter, 2004). The reason for its significant effect on vertebrates has to do with its pharmacological nature. Coniine acts solely on the central nervous systems of affected subjects, targeting neurons in the same way as a common anaesthetic (Frank *et al.,* 1995). The most detrimental action that coniine takes is depressing the neuronal potential for postsynaptic signalling (Sampson *et al.,* 1966). In many similar cases, epinephrine is effective in restoring the function of neurons, but studies have show that it is ineffective in reversing the effects of coniine (Sampson *et al.,* 1966). As a result, coniine's action is similar to an overdose of anaesthesia, with the depressed neural function causing complete muscle paralysis (Westbrook *et al.,* 1973). In human adults, the paralysis caused by the ingestion of as little as 200mg of hemlock oils has dire effects on the respiratory system, resulting in death within hours (Westbrook *et al.,* 1973; Frank *et al.,* 1995).

Considering how low of a dose is necessary to kill an average human adult, the danger to livestock and other wildlife is evident. Hemlock is notorious for invading grazing areas, as it has the potential to out-compete the more desirable native species in wet meadowlands and pastures (Greary and Murphy, 2000; Andrew, 2001). This increased prominence in pastures can have drastic effects on livestock, which would be rendered unusable if killed by ingestion of hemlock, as the toxins in their body would persist following death (Greary and Murphy, 2000). The only identified predator that is effective in eradicating hemlock is the moth *Agonopertix alstroemeriana* (Castells, 2005; Castells and Berenbaum, 2006). The problem with this is that *A. alstroemeriana* has difficulties breeding in the wild, so human intervention in the form of laboratory rearing of the moth is necessary, and is not nearly enough to combat the massive spread of hemlock across the continent (Castells and Berenbaum, 2006). It is possible that other species of insects may develop a resistance to the toxins in hemlock, but which species may do this remains to be seen.

Allelopathy: Hemlock as a Vector for Plant Disease

To add to hemlock's powerful ability to invade, the plant also has the capacity to serve as a vector for diseases deadly to other plants (Hillman, 1997; Andrew, 2001). This remarkable allelopathic trait has been utilized in hemlock's spread through agricultural areas and, in combination with the deadly toxins produced, renders hemlock nearly unstoppable without human intervention (Al-Barwani and Eltayeb, 2004). Hemlock is a vector for *Xylella fastidosa*, a bacterial pathogen that resides in the xylem of plants and blocks water flow (Hopkins, 1989). This disease can have devastating effects on crops, and is particularly prominent in the vineyards of California (Hillman, 1997). Certain crops such as alfalfa suppress the allelopathic effects of hemlock after a first cutting, but many crops are left vulnerable to the lethal power of

the plant (Greary and Murphy, 2000).

Impact and Human Intervention

For the reasons discussed, poison hemlock is a very undesirable plant species to humans. Its damage to crops and livestock harms the economy, and its deadly poison has the potential to harm or kill wildlife and humans themselves. Humans have made many attempts to eradicate it in many areas, but to no avail (Greary and Murphy, 2000). Hemlock, embodying the essence of a truly invasive species is persistent enough to survive and continue its domination of all areas in which it has germinated. As a persistent, effectively self-defending plant that is able to disperse and germinate in times when other plants are unable to be found, all that humans can do is treat local areas with herbicides to protect small portions of land from the implications of the poisonous plant (Vetter, 2004). Having evolved to be a truly successful invader, with incredibly high allelopathic potential, it is clear that hemlock is a Darwinian nightmare to humans.

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