Water Chestnut (*Trapa natans)*

Eurasian water chestnut (EWC), *Trapa natans,* is a floating aquatic plant that has been established in the United States for over a hundred years*. T. natans*'s persistent seeds and extensive vegetative growths make it an effective invader. It is known to form nuisance mats in lakes and rivers which can alter aquatic ecosystems as well as hinder economies associated with the waterway (Les & Mehrhoff, 1999). Since its originally introduction, it has spread throughout southern New England and is currently established in southern Lake Champlain and counties surrounding the Adirondack Park (Sterner, 2006; USDS, 2012).

T. natans is a submerged aquatic macrophyte with floating foliage and is best suited for shallow, nutrient-rich lakes and slow flowing rivers. It can grow at depths between 1/10m to 5m, but prefers 3/10m to 2m of water (Papaestergiadou & Babalonas, 1993). Generally it is found within a pH range of 6.7-8.2 and wide array of calcium carbonate concentrations from 12-128mg/L (Naylor, 2003). EWC has floating rosettes of leaves which occur around a stem rooted sediment. As the plant produces new foliage from the central terminal meristem in the rosette, the older leaves with developing fruit release from the parent plant (Groth, Lovett-Doust, & Lovett-Doust, 1996). This in effect creates a clone of the parent plant that is able to redistribute and re-root with maturing fruit (Groth et al., 1996). The developing woody fruit has four sharply pointed horns, bearing a single, viable seed (Naylor, 2003).

Like most nonindigenous species, *T. natans* is native to Eurasia. In North America it has been found as far north as Quebec and throughout the Northeastern United States including NY, PA, MD, DE, MA, VY, VT, and NY (USDS, 2012). Since 1875 anthropogenic practices through aquaculture and intentional planting have enabled this plant to first colonize natural waters near Cambridge, MA and quickly spread to a multitude of watersheds (Countryman, 1970). After its first appearance on the Hudson River in 1884, EWC has been distributed throughout New York's waterways (Wibbe, 1886). Currently this invader persists in the Great Lakes basin in Lake Ontario, the southern stretches of Lake Champlain, and numerous countries surrounding the Adirondack Park, like St. Lawrence and Saratoga (USDS, 2012).

There have been multiple vectors associated with assisting EWC in its spread and distribution. It has been proposed that the spiny seed pod of the invader can attach to the plumage of water fowl, and therefore can be transported from one body of water to another. However the weight of the seed pod (6g) makes it unlikely for it to stay attached for prolonged flights (Les & Mehrhoff, 1999). Plus there is growing evidences pointing to human mediated spread of *T. natans.* For example it has been suggested that EWC's establishment in Lake Champlain is a result of the spiny nut attaching to ropes and nets from the infested Hudson River and transporting them via the canal (Countryman, 1970)

T. natans is a successful invader, partly due to its annual reproductive methods. Around the middle of May in the northeastern United States EWC's seeds germinate in the sediments of river and lakes (Methe, Soracco, Madsen, & Boylen, 1993). By early June a dense canopy of floating rosettes forms on the water's surface (Groth et al., 1996). At this time clonal fragmentation of rosettes containing maturing fruits occurs off the parent plant (Groth et al., 1996). These fragmented clones reestablish, survive, and mature seeds during the rest of the growing season, while the parent plants are maturing another batch of seeds and possibly rearing another clone for fragmentation (Groth et al., 1996). By August the first of the seeds complete maturation, and upon abscission they fall to the sediments below (Methe et al., 1993). Seed production and maturation continues until senescence. In dense growths of EWC, as many as 170 seeds per m^2 have been documented (Methe et al., 1993). The seeds then overwinter to the next growing season, or remain dormant and viable in the sediments exceeding 3 years (Kunii, 1988).

The clonal propagative method allows EWC to quickly establish itself in new locations and exhibit signs of explosive growth (Groth et al., 1996). When these plants' initial densities start low, it takes on a slightly different biology than plants in high density populations. Crowed sites with high densities have smaller leaves and suffer from constant mortality throughout the growing season (Groth et al., 1996). While plots starting with low densities show no particular signs of die off until the end of the season's senescence. Most importantly, low densities of plants can produce more seed maturing clones than high densities, which concomitantly allows for greater vegetative propagation and seed production (Groth et al., 1996). These differences allow EWC to quickly build a seed bank and form nuisance growths in newly established locations (Groth et al., 1996).

Noxious growths often caused by EWC can result in changes within the aquatic ecosystem. Firstly, the dense, floating foliage of EWC can outcompete native aquatic plants for light and space (Groth et al., 1996; Les & Mehrhoff, 1999; Naylor, 2003). Cover has been recorded to be 100% in a high density plots, and a varied flora bed can turn into a monoculture of EWC within five years of establishment (Groth et al., 1996). Additionally alterations in macroinvertebrates communities are consistent with EWC colonization (Strayer, Lutz, Malcom, Munger, & Shaw, 2003). There can be higher densities of macroinvertebrates in *T. natans* beds than native *Vallisneria americana* which is due to the higher plant biomass associated with *T. natans* (Strayer et al., 2003). The replacement of *V. americana* by *T. natans* may lead to an increase in system-wide biodiversity and food for sport fish, but this food may remain unavailable (Strayer, Lutz, Malcom, Munger, & Shaw, 2003; Hummel & Findlay, 2006) Dense beds have been linked to hypoxia or anoxia with dissolved oxygen as low as 4.5mg/L, which is not suitable for sensitive fish and invertebrates (Caraco & Cole, 2002).

Furthermore, the EWC can also have negative effects on water based industry. The thick growths of this invader make recreational and commercial navigation nearly impossible. These beds are also poor habitats for highly sought after sports fish and provide little food for waterfowl which can decimate both hunting and fishing economies (Caraco & Cole, 2002; Hummel & Findlay, 2006; Les & Mehrhoff, 1999). Also the sharply spiked, woody seed pod produced by EWC can puncture swimmers' feet and keep many tourists off popular beaches (Naylor, 2003).

There has been large scale management plans implicated because of EWC's ecological and economical detrimental impacts. In Lake Champlain and other Vermont waters management cost over $400,000 in 2009 and $8.3 million since 1982 (Hunt & Marangelo, 2009). If an infestation does occur, some control efforts include (Hunt & Marangelo, 2009; Naylor, 2003):

- Harvesting→most used (Naylor, 2003)
    - Hand→successful for small populations
    - Mechanical→to clear large clogged waterways for commercial transportations
    - Important to harvest prior to seed maturation and abscission (Methe et al., 1993).
    - Seeds lay dormant for many years→consecutive harvest seasons required for successful control or possible eradication (Hunt & Marangelo, 2009; Naylor, 2003)
    - Remaining fragments are viable
- Biological
- Chemical control

Eurasian water chestnut is an aquatic macrophyte with floating foliage. It can quickly colonize a myriad of habitats dues to its high clonal fragmentation and seed production. Since its intentional introductions in the late 1800s, EWC has been shown to outcompete and destroy native plant communities, alter the dissolved oxygen in its beds, shift macroinvertebrate communities, ruin recreational activities and economies, and impede commercial transport (Hummel & Findlay, 2006; Hunt & Marangelo, 2009; Les & Mehrhoff, 1999; Naylor, 2003; Strayer et al., 2003; Wibbe, 1886). With its naturalization and distribution surrounding the Adirondack Park, it is important to eliminate its spread into the inner waterways of the Park.

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