European Frogbit (*Hydrocharis morsus-ranae)*

European frogbit, *Hydrocharis morsus-ranae,* is an aquatic invader with floating leaves from, as its name suggests, Europe. Its attractive floating foliage and hardy characteristics has made this plant highly sought after in the aquarium trade. Since it has been released from cultivation in Canada European frogbit has greatly expanded its naturalized distribution through human activities in North America (Calting, Mitrow, Haber, Posluszny, & Charlton, 2003; Rothlisberger, Chadderton, McNulty, & Lodge, 2011). With its vegetative growth, *H. morsus-ranae* can form impenetrable plant beds (Calting, Spicer, & Lefkovitch, 1988). These mats can compete with native plants and alter the aquatic community (Calting et al., 1988). Additionally, recreational and commercial activities can be hindered by the dense growths (Kuebbing, Smith, & Wills, 2011). Currently this invader is established in waters surrounding the Adirondack Park and has been sighted with in the Blue Line (Smith, 2012).

Apart of the Hydrocharitaceae family, European frogbit is an annual free-floating macrophyte (Calting et al., 2003; O'Neill, 2007). It is free-floating in the sense that its long roots, up to 50cm, are typically suspended in the water column rather than attaching to the sediment beds. As a stoloniferous plant with steam like extensions producing new growth, an individual can range from .1-1.5m across with distinct rosettes or plantlets varying between 1 and 30cm (Calting et al., 2003). The rosettes contain entire, heart-shaped leaves, 1.2-6cm long and 1.3-6.3cm wide (Calting et al., 2003). Green marks the topside of the leaves, while a purplish-red spongy underside is characteristic of European frogbit (O'Neill, 2007). Most but not all populations are considered dioecious, displaying emergent, small, white solitary female and clustered male flowers (Scribailo & Posluszny, 1984). However, some

argue European frogbit is actually monoecious. It is very difficult to examine the entire plant because the stolons tangled with one another and commonly break upon inspection (Lindberg, 1873).

Typically the populations of European frogbit are usually dominated by a single sex flower and few seeds are produced (O'Neill, 2007; Scrivailo & Posluszny, 1984). Even in plots containing both sexes and seed production is high, averaging 1,000 seed/m^2, few seedlings are incorporated into the future populations (Burnham, 1998; Calting et al., 2003). Therefore most of European frogbit's reproduction is vegetative through the production of stolon buds and overwintering/dormant stolon buds, also known as turions (Calting et al., 2003).

Late April through early May turions, the overwintering vegetative buds, germinate in the sediments and small juvenile rosettes rise to the water's surface (Calting & Dore, 1982; Cook & Lound, 1982). By the middle of May plants are usually well developed and large clonal mats begin to form from stolons. With the rapid development of stolon, new rosettes form which in turn sends out more stolons (Calting et al., 2003). When the end of June arrives a single spring turion usually has given rise to six to ten rosettes through stoloniferous growth, and each rosette can develop and produce around ten turions/dormant buds (Calting et al., 2003; Scribailo & Posluszny, 1984). As the plants begin senescence (grow old/die), turions complete maturation and settle to the sediments (Cook & Lound, 1982).

European frogbit can occupy and sometimes dominate a wide range of habitats. It prefers low wave energy areas like swamps and marshes; backwaters; bays, sheltered, coves, and shorelines of lakes, rivers, or streams (Calting & Dore, 1982; Calting et al., 2003; O'Neill, 2007). *H. morsus-ranae* is tolerant of varying trophic conditions from oligotrophic to hypereutrophic but is typically found in mesotrophic to slightly eurtrophic waters with a pH of 6.5-7.8 (Calting & Dore, 1982; Calting et al., 2003; Tosheva & Traykov, 2012; Zhu, Eppers, & Rudstam, 2008). Some populations occur over organic substrates, often peaty sediments, suggesting that European frogbit tolerates calcium poor water (Calting & Dore, 1982; Cook & Luond, 1982). However there are also records of it establishing and forming nuisance growths in calcium rich waters (Calting & Dore, 1982). Additionally, limited light inhibits the germination of dormant buds, and areas with high turbidity, fertilizer eutrophication, or soil erosion are less suitable for European frogbit colonization (reviewed in Calting et al., 2003; Richards & Blakemore, 1975).

Its generalist habitat preferences as well as human intervention through intentional planting and aquatic plant hitchhiking has enabled *H. morsus-ranae* to successfully establish throughout the world and invade the northeastern United States, Washington, and southeastern Canada (Calting & Dore, 1982; Minshall, 1940; O'Neill, 2007; Rothlisberger et al., 2011). Since 1932, when it was intentionally introduced for the aquarium trade from Arboretum of Central Experimental Farm in Ottawa, Canada and found growing wild in Dows Lake, it has spread throughout the Great Lakes Basin and United States at 15.6km/year (Calting et al., 2003; Calting & Porebski, 1995; Minshall, 1940). This spread is largely due to intentional or accidental planting, but within a waterway European frogbit can spread quickly because it is free-floating. One plantlet can become detached from the parent and drift to another portion of the waterway where it can continue growth and turion maturation. In New York the Oswegatchie River (the first infested water body) and Lake Champlain have supported European frogbit populations since 1974 and 1993, respectively (Calting et al., 2003; Marsden & Hauser, 2009). It is now common in in counties

surrounding the Adirondack Park and has been sighted in the Grass River of the western Adirondacks and a small private pond in Essex County (Smith, 2012).

The establishment of European frogbit comes with deleterious effects on human based activities and the environment (Calting et al., 2003; O'Neill, 2007; Pimentel et al., 2005; Simberloff, 2005). Commercial industry (i.e. clogging intake pumps, water traffic) and recreational activities (i.e. swimming, fishing, boating) can be inhibited by European frogbit's thick, vexitious growths (Calting et al., 2003; Marsden & Hauser, 2009). As for the virtue of the environment, *H. morsus-ranae* can become dominant or codominant in local aquatic ecosystems within 5 years of its establishment (Calting et al., 2003). Through rapid vegetative propagation, dense plots can form monocultures and diminish growth of native submersed plants by limiting light and competitively occupy habitats (Calting & Dore, 1982; Calting, Spicer, & Lefkovitch, 1988). Also native, aquatic plant beds support a greater diversity of associated fauna like macroinvertebrates than European frogbit, and consequently an invasive establishment of European frogbit can reduce native flora and fauna biodiversity (Calting et al., 2003; Calting et al., 1988; Kuebbing et al., 2011; O'Neill, 2007). Furthermore, nuisance growths in Oneida Lake, NY have been observed with over 500 plantlets/m^2 and dissolved oxygen levels as low as 1.9mg/L underneath the plants (Zhu, unpublished data reviewed in Zhu et al., 2008). Other changes in oxygen could occur in autumn when plants die and decomposition begins. The large amount of biomass produced by European frogbit may largely increase the dissolved oxygen depletion which can be stressful or fatal for fish and other aquatic organisms (Calting et at., 2003).

A crew of volunteers harvest European Frog-bit from a wetland in Charlotte. Photo by Caludia Marshall, VPR.

Management has been sought to control established populations and condense the distribution of European frogbit because of its damaging impacts on the ecosystem and water based industry. Studies predicting the success of invasions and propagule pressures of European frogbit are vital tools for allocating limited resources and determining management goals and methods (Zhu et al., 2008). Control options include (Kuebbing et al., 2011):

- Chemical
- Biological
- Harvesting
    - Most widely used and should be done prior to turion development
    - Proven successful in eradication if populations are caught early (Smith, 2012; Kuebbing et al., 2011)

- Provided temporary relief in established populations and subsequent years of harvesting required (Kuebbing et al., 2011)

In Town Farm Bay and Kimball Brook of Charlotte, VT European frogbit has been hand-harvested since 2009 (Kuebbing et al., 2010). After three harvest seasons, 5468 paid and volunteer man hours, 42.5 tons of European frogbit has been collected and composted (Kuebbing et al., 2011). Successfully, most managed areas' coverage has been reduced to 6% (Kuebbing et al., 2011). Managers are aspiring to cut back the majority of hand-harvesting by 2015 while monitoring, public education, and prevention outreach are permanent missions (Kuebbing et al., 2011)

European frogbit is a decorative free-floating aquatic plant. It can tolerate a wide range of environments but prefers low wave energy areas of lakes and rivers (Calting et al., 2003). In optimal conditions European frogbit can form dense, pernicious vegetative mats through stoloniferous growth. The plots can become impassable for commercial and recreational vessels plus crowd out native aquatic plants (Calting et al, 1988; Kuebbing et al., 2011). Human mediation through the aquarium trade and hitchhiking by boats, trailers, aquatic equipment, etc. has enabled *H. morsus-ranae* to expand its range about 15.6km/year in North America (Calting et al., 2003; Calting & Porebski, 1995; Rothlisberger et al., 2011). Its negatives impacts and appearances in the Adirondack Park make it one of the most unwanted and recognized aquatic invaders.

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