

Curly Leaf Pondweed (*Potamogeton crispus*)



Biological invaders, like *Potamogeton crispus* L. are huge threats to biodiversity in the ecosystem and associated aquatic industry (Sala et al., 2000). This invasive pond weed is indigenous to Eurasia and can form thick monocultures. It is especially persistent because it has two reproductive methods by seeds and dormant buds known as turions (Calting & Dobson, 1985). Curly leaf pondweed has been established in the United States for over 100 years and successfully invades waters in the Adirondack Park. Since invasive aquatic plants are known to affect both aquatic ecology and related economies, it is important to understand the biology and ecology of *P. crispus* (Sala et al., 2000).

Native to Eurasia, curly leaf pondweed is now a cosmopolitan species with a worldwide distribution in Africa, Australia, and North America (Stuckey, 1979). Exactly when it was first presented to the United States is unknown, but the most agreed upon time is during the mid-1800s (Calting & Dobson, 1985; Stuckey, 1979). The original means of introduction is also unidentified, but escapement from horticultures seems to be the most plausible culprit. Since the 1840s, when the earliest verifiable wild collection of *P. crispus* was found in waters around the Philadelphia, PA area, it has spread throughout the Northeastern United States within a few decades (Stuckey, 1979). Curly leaf pondweed is now found in nearly all 50 States and as far north as Calgary, Canada (Calting & Dobson, 1985; USDA, 2012). It infests waters throughout the Great Lakes basin and the state of New York (USDA, 2012). In the Adirondack Park curly leaf pondweed has been identified in Lower Saranac Lake, Lake Flower, and Paradox Lake of Franklin and Essex counties as well as other water bodies (USDA, 2012).

Curly leaf pondweed is a submerged aquatic macrophyte. It is a perennial but behaves as a winter annual through the production of dormant buds called turions (Calting & Dobson, 1985).

Depending on the season, curly leaf pondweed displays two types of vegetative leaves. In the early spring-summer, when its biomass is the greatest, leaves are green, oblong to obovate, .75-1.5cm wide and 3-8cm long (Calting & Dobson, 1985). The leaves commonly resemble lasagna noodles which are crisp and brittle with serrated margins and round tips. The winter foliage leaves differs by being relatively narrow (50-75mm) and flexuous with flat margins and acute tips (Calting & Dobson, 1985).

This pondweed can tolerate diverse aquatic environments. Water chemistry variables that have been measured in curly leaf pondweed infested waters include nitrate concentrations ranging from 2.0-24mg/L with a mean of 8.96mg/L; phosphate concentrations ranging from .2-1.12mg/L with a mean of .25mg/L; and pH ranging from 6.7-9.8 with a mean of 7.6 (Calting & Dobson, 1985). *P. crispus* has been recognized in aquatic systems where conductance is relatively high (400 micromhos/cm²) and can be found in alkaline, calcareous, and brackish waters (reviewed in Calting & Dobson, 1985; McCombie & Wile, 1971). Furthermore, curlyleaf pondweed can also establish communities in polluted waters with high metal concentrations (Ali, Tripathi, Rai, Pal, & Singh, 1999). Curlyleaf pondweed's tenacity to a wide range of habitats has enabled its world wide distribution and colonization.

P. crispus has two possible reproductive and propagative pathways. The main strategy is through the formation of dormant buds, while the other is seeds by wind pollinated flowers (Sastroutomo, 1981). Seed production is relatively high in *P. crispus*, and a single plant can produce 960 seeds if the seeds are continually removed (Yeo, 1966). However the formation of dormant buds is just as lucrative as seed productions. A 5.9m² monoculture of *P. crispus* is able to produce 23,000 dormant apices, and a single plant can yield over 900 dormant apices throughout a season (Yeo, 1966).

The dormant apices are the main propagation strategy. At the same time as flower bud initiation, the apices begin to develop in early spring from axillary buds along the stem (Calting & Dobson, 1985). Each dormant apex often consists of five to seven dormant buds (turions) which any or all can give rise to a new plant (Calting & Dobson, 1985). Usually apices development period begins in May and is completed by June or later depending on water temperatures (Sastroutomo, 1981). The dormant buds take about two weeks to mature on the plant before abscission occurs, and they sink to the sediments. After the turion output period, the spring-early summer foliage loses its buoyancy and dramatically dies back around early July (Sastroutomo, 1981). The turions lie dormant in the sediment over the most productive and competitive portion of the summer (Calting & Dobson, 1985). With the onset of colder water temperatures in the fall the dormant buds germinate in the sediments and begin to grow winter foliage that can persist under thick ice and snow cover (Calting & Dobson, 1985; Tobiessen & Snow, 1984). In winter-early spring or when the ice melts, winter foliage dies off and is replaced by early spring-summer foliage. This new summer foliage in turn gives rise to the next season's turions and seeds.

This summer-dormancy cycle maximizes the effective use of spring's untapped available nutrients prior to other aquatic species and reduces competition for nutrients and light during the most productive period of the summer (Nicholas & Shaw, 1986; Tobiessen & Snow, 1984). These strategies provide early competitive advantages for curly leaf pondweed, and a better understanding of its life cycle, bud formation, and dormancy period could enable more effective management practices.

Depending on the growth and establishment, curly leaf pondweed can have deleterious or advantageous effects on the economy and ecosystem. During the early spring-summer growths, the plants can form dense monocultures which can cover large areas of the water surface (Calting & Dobson, 1985; Cypert, 1967). These dense, pernicious growths can impede water flow in irrigation canals and restrict water based recreation (Cypert, 1967). A lake in northern Tennessee had experienced such growths during sport fishing's peak time which severely hindered the season and related economy (Cypert, 1967). Due to curly leaf pondweed's jumpstart on the season, it can crowd out other native aquatic plants (Nicholas & Shaw, 1986). Even after *P. crispus*'s summer die back, the crowded native plants do not show signs of recovery (reviewed in Calting & Dobson, 1985). The dieback also increases the nutrient load in the water column which subsequently can lead to harmful algae blooms and oxygen depleted water (reviewed in Calting & Dobson, 1985).



However there have been beneficial trends noted with *P. crispus*'s establishment. Firstly, curly leaf pondweed is under review for the use in phytoremediation and biomonitoring in polluted waters because it has been shown to accumulate considerable amounts of metals like Cr, Cu, Fe, Mn, Ni, Pb, and Zn (Ali et al., 1999). Also the huge biomass created by curly leaf pond weed is consumed by other aquatic species. Not only do herbaceous zooplanktons consume the foliage, but it also provides a great energy source for dabbling, diving ducks and coots (Calting & Dobson, 1985; Cypert, 1967; Hunt & Lutz, 1959). Additionally this pondweed can produce over 4.5-5.5 million seeds in one acre which can support 500-1000 mallard size ducks for one day (Hunt & Lutz, 1959). Finally, if curly leaf pondweed does not produce unfavorable growths, it can provide excellent cover for sport fish like bass (Bonvechio & Bonvechio, 2006; Wiley, Gorden, Waite, & Powless, 1984). Depending of the severity of its growth, *P. crispus* can be linked to both beneficial or insalubrious effects on the ecosystem and related industry.

Since curly leaf pondweed can form pestiferous growths that distress the ecosystem and the economy, management methods have been implemented and include:

- Chemical herbicides → most common management practice
 - Type of herbicide and time of treatment are important to consider for the greatest effect on reducing biomass and turion formation → application during the lowest point of carbohydrate storage (January and April) when the plant is most vulnerable to management and turion development has yet occurred (Woolf & Madsen, 2003)
 - Endothol and diquat treatments in the early spring (May and March) have resulted in effective biomass reduction and the inhibition of turion production (Netherland, Skogerboe, Owens, & Madsen, 2000; Poovey, Skogerboe, & Owens, 2002).
 - If management is sought later in the year, turions can still form and remain viable for the next season or even years (Johnson, 2010).

- Early spring management practice could minimize the impact of herbicides on native plants species, which are typically dormant during this period (Woolf & Madsen, 2003)
- Biological → Triploid grass carp (*Ctenopharyngodon idella*)
 - Grass carp have been shown to have a preference for curly leaf pondweed above other aquatic plants (Hamel, *n. d*; Pauly et al., 1994)

Curly leaf pond weed is an aquatic macrophyte invader, indigenous to regions in Eurasia, and has now colonized throughout the world and North America (Stuckey, 1979). As a submersed aquatic perennial, *P. crispus* displays two distinctive vegetative foliage in the summer and winter periods (Calting & Dobson, 1985). It has dual reproductive strategies through the production of seeds and turions. When *P. crispus* forms thick growths or monocultures in the water column it can diminish aquatic based industry and alter sport fish populations (Cypert, 1967). It is already established in waterways throughout the Adirondack Park including Essex and Franklin counties, and therefore it is imperative to be aware of its potential threats and eliminate its spread into nearby waters bodies.

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