A Winter's Tale: Aquatic Plants Under Ice

Susan Knight

Submersed aquatic plants face some hardships not encountered by terrestrial plants. Water, with its dissolved and particulate components, interferes with light penetration for photosynthesis. The sluggish diffusion of gases in water can hinder carbon absorption. Because of their close relationship with terrestrial angiosperms, most aquatic plants hold their flowers up in the air for insect or wind pollination, but have only limp underwater structures for support. In regions where the water bodies freeze, winter presents its own challenges for aquatic plants. Just as they exhibit many adaptations to dealing with life underwater during the growing season, macrophytes also tackle winter survival in unusual ways. In winter, the plants may have to deal with anoxia, or ice may form all the way to the lake bottom near shore. However, because the entire lake usually doesn't freeze solid, the underwater environment is, in some ways, a more benign environment than the frozen landscape faced by land plants. Winter conditions create opportunities and constraints on aquatic plants that challenge their survival until they start growing again the next spring.

Two features of submersed aquatic plants make them especially well adapted to surviving winter underwater. First, they rely hugely on vegetative reproduction and second, they are notoriously plastic in their shape and dimensions. The relative constancy of the aquatic environment is optimal for vegetative growth. Many authors, especially C.D. Sculthorpe (1967), who wrote the venerated *The Biology of Aquatic Plants*, have noted that possibly because of the uniformity of the environment, genetic variation provided by sexual reproduction is not as essential for survival. Aquatic plants are so adept at vegetative or clonal growth, it may be a deterrent to flower and fruit development. One of the few annual aquatics, bushy pondweed (*Najas flexilis*), is a pioneer species that tends to colonize new areas and is a rare exception to the rule of vegetative over sexual reproduction in aquatics. Almost all aquatic plants are perennials and rely on vegetative reproduction not only to spread within a lake but also to survive from year to year. (See *Through the Looking Glass* (Borman et al. 2014) in each "Through the Year" section on how different species survive the year.)

Vegetative Reproduction

Rhizomes. Many of the structures that facilitate vegetative reproduction also work as overwintering structures. The large fleshy rhizomes (underground stems) found in the pond lilies *Nuphar* (Figure 1) and *Nymphaea* are storage organs for carbohydrates translocated from the photosynthesizing leaves. After dormancy, the carbohydrates from the rhizome are mobilized and invested in new leaves. Once they start photosynthesizing, these new leaves will repay the carbon debt to the mother plant, which can then afford to put out even more leaves. Many aquatic plants have less substantial, but still

Figure 1. Spatterdock (Nuphar variegata) *rhizomes.* Photo: Paul Skawinski.

important rhizomes or stolons (above ground stems) employed to spread the plant during the summer. Strings of individual plants such as wild celery (*Vallisneria americana,* Figure 2), dwarf watermilfoil (*Myriophyllum tenellum*) or creeping spearwort (*Ranunculus flammula*) can be easily uprooted with adjoining plants clearly connected to their neighbors. Some of these rhizomes and stolons stay in place from one season to the next and serve as overwintering tissues.

Tubers. Some plants form tubers (or, the slightly different "corms") that are also fleshy carbohydrate caches. Species such as arrowhead (*Sagittaria latifolia*) and sago pondweed (*Stuckenia pectinata*) produce these tubers in late summer and rely on them as overwintering organs. Indeed, another common name for *Sagittaria latifolia* is duck potato (Figure 3), named for the tubers that are highly valued and devoured by waterfowl. Just as with the rhizomes, tubers (that escape the ducks) provide carbohydrates to initiate new growth in the spring, with new tubers produced late the following summer.

Figure 3. Right: Common bladderwort (Utricularia vulgaris) *turion; left center: Fries' pondweed* (Potamogeton friesii) *turion; top: Arrowhead or duck potato* (Sagittaria *sp.*) *tuber.* Photo: S. Knight.

Figure 2. Wild celery (Vallisneria americana) *rhizome and storage buds.* Photo: S. Knight.

Turions. The most aquatic plant-specific overwintering tissues, without any exact terrestrial equivalent, are winter buds called turions. These are modified buds, located at the stem and branch tips where there would be normal meristematic tissue in the growing season. Turions, like other overwintering organs, are stuffed with carbohydrates and sometimes covered with a protective mucilaginous coating.

Several species of pondweeds have turions that help the plant overwinter, and these are often distinctive enough to aid in species identification. Though some are barely distinguishable from the normal plant tip, such as Vasey's pondweed (*Potamogeton vaseyi*) and leafy pondweed (*P. foliosus*), others are quite distinctive. Curly-leaf pondweed (*P. crispus*, Figures 4 and 5) has perhaps the most distinctive turions of all the pondweeds. The turion is almost woody, with thickened, horny leaves much like a short piece of a pine cone. Flat-stem pondweed (*P. zosteriformis*, Figure 6) has large and conspicuous turions that start forming early in the summer. It is possible to find a flat stem pondweed with a beefy old turion at the base of the plant that survived the winter and sprouted in the spring, and a new turion at the tip. Fries' pondweed (*P. friesii*, Figure 3) has striking, fan-shaped turions, with inner and outer leaves of the modified bud at right angles to each other. Though thin-leaved pondweeds can be tricky to identify, the early formation of turions on Fries' pondweed make it one of the easiest to identify through much of the summer. The turions of pondweeds usually fall off the plant and will sprout into shoot and roots the next spring.

Watermilfoil (*Myriophyllum*) also has several species with turions. Northern watermilfoil (*M. sibiricum*, Figures 7 and 8) and whorled watermilfoil (*M. verticillatum*, Figure 9) produce many turions with dark green, dwarfed leaves with extremely short internodes packed tight around the stem axis. The turion leaves have fewer segments and are shorter and thicker than normal leaves. Whorled watermilfoil turions are baseball bat-shaped, with the fat end at the tip and located all over the plant. Northern watermilfoil turions look more like

Figure *4. Curly-leaf pondweed* (Potamogeton crispus) *with fruits (left) and turions (center).* Photo: Frank Koshere.

Figure 5. Curly-leaf pondweed (Potamogeton crispus) *turion.* Photo: Frank Koshere.

green pencils – thicker than the stem but not as broad at the tip as those on whorled watermilfoil. These are mostly at the plant tip, with fewer side turions. After detaching from the parent plant, watermilfoil turions drop off and sink or float. When the turion expands in the spring, the short internodes elongate, and early in the summer the stubby turion leaves are clearly visible at the base of the plant (Figure 10). Within a short time, new normal leaves will appear.

Several bladderworts, including common (*Utricularia vulgaris*, Figure 11), flat-leaf (*U. intermedia*), twin stemmed (*U. geminiscapa*) and small (*U. minor*) bladderworts also produce remarkable turions. Like the watermilfoils, the bladderwort turion leaves are shorter and thicker than normal leaves, and they lack the bladders characteristic of this genus. The bladderwort turions are rounder and more fist-shaped than watermilfoil turions. The common bladderwort turions often resemble a fat green mitten, where the "thumb" is a smaller turion from a side branch. The bladderwort turions have a mucilaginous coating to further protect them. The umbel-like large purple bladderwort does not make such a compact turion, but has thickened and inwardly curled "leaves" resembling the late summer tips of Queen Anne's lace. Since bladderworts do not have roots or any underground tissues, the turions are the only way a bladderwort can survive the winter, aside from seed production.

Several other aquatic plants produce some sort of turions, though not as conspicuous as those of the pondweeds, watermilfoil or bladderworts. Water shield (*Brasenia schreberi*) produces turions at the tips of trailing stems that are swollen with starch reserves and are critical to overwintering. In some duckweeds, notably turion duckweed (*Lemna turionifera*) and large duckweed (*Spirodela polyrhiza*) the entire plant is modified for winter so that it is about half its usual size and loaded with starch. With most of the air spaces squeezed out, these plants that normally float will sink to the sediments for the winter.

Other Strategies. Coontail (*Ceratophyllum demersum*, Figure 12), water marigold (*Bidens beckii*, Figure 13) and Elodea (*Elodea canadensis*) have densely crowded plant tips as they prepare for winter. These plants always have dense tips, but in the fall, the internodes become shorter, and the leaves are more heavily laden with starch. These leaves are also physically tougher than usual, and better able to weather the winter. The tips may remain attached to the plant, or some may fall to the bottom. Elodea will develop adventitious roots once they start to sprout in the spring; coontail never develops roots.

Many water birds feast on aquatic plant turions and tubers. While they can have a negative effect on tubers, birds can also aid in the distribution of aquatic plants if propagules attach to the bird,

Figure 6. Flat-stem pondweed (Potamogeton zosteriformis) *turion.* Photo: S. Knight.

Figure 7. Northern watermilfoil (Myriophyllum sibiricum) *turions.* Photo: S. Knight.

Figure 8. Northern watermilfoil (Myriophyllum sibiricum) *turions.* Photo: S. Knight.

Figure 9. Whorled watermilfoil (Myriophyllum verticllatum) *with turions.* Photo: Paul Skawinski.

or pass through the gut to be defecated in a new water body. The presence of waterfowl can be a proxy for the health of the aquatic plant community.

Sexual Reproduction

Water birds are also fond of aquatic plant fruits and seeds. While most aquatic plants are angiosperms and therefore produce flowers and seeds, only a few reproduce sexually every year. Water nymphs (*Najas* spp., except *N. guadalupensis*), waterworts (*Elatine* spp., Figure 14) and wild rice are annuals and must produce flowers and seeds each year in order to make it to the next season. The water nymphs and waterworts are especially remarkable since they flower underwater, and must rely on the vagaries of water currents to carry pollen from one

Figure 10. Early spring expansion from a Northern watermilfoil (Myriophyllum sibiricum) *turion showing thick, small turion leaves with a reduced number of segments.* Photo: Paul Skawinski.

Figure 11. Common bladderwort (Utricularia vulgaris) *turion.* Photo: S. Knight.

Figure 12. Coontail (*Ceratohyllum demersum*) has thickened tips for overwintering. Photo: S. Knight.

Figure 13. Water marigold (Bidens beckii) *has a turion-like thickened tip for overwintering.* Photo: S. Knight.

plant to another. Some pondweeds, such as sago pondweed (*Stuckenia pectinata*, Figure 15) usually produce a profusion of fruits, and some are likely to escape herbivory and germinate into new plants. Most other aquatics also produce flowers and fruits at least occasionally, and, while important for increasing genetic diversity and long-range dispersal, sexual reproduction does not seem to be critical for routine overwintering survival.

Exotic Species

Aquatic environments are notorious for experiencing explosive growth of exotic species, such as curly-leaf pondweed, Eurasian watermilfoil (*Myriophyllum spicatum*), among others. Part of the reason these plants become so invasive is their ability to grow rapidly during the growing season and overtop native plants. But it is also important to understand how these successful interlopers manage to survive from year to year in their adopted environment. As discussed earlier, curly-leaf pondweed (Figures 4 and 5) produces a tremendous number of turions early in the summer. In fact, curly-leaf pondweed turions are

Figure 14. Tiny waterwort (Elatine minima)*, an annual with underwater pollination.* Photo: S. Knight.

Figure 15. Sago pondweed (Stuckenia pectinata) *with fruits.* Photo: Paul Skawinski.

considered more of an over-*summer*ing bud, as they are produced in early summer and often sprout in late summer or early fall.

These turions are resistant to desiccation and can survive being out of the water for weeks. Unlike whorled and northern watermilfoil, Eurasian watermilfoil does not produce turions. However, the plant does not die back to the lake bottom each year, but some part of the plant remains alive all winter, ready to sprout as soon as there is enough light in the spring. Mature Eurasian watermilfoil plants fragment in fall, often with adventitious roots already established and ready to take root. These fragments, like the parent plants, survive the winter, and start growing once there is enough light.

Starry stonewort (*Nitellopsis obtusa*), a relative of *Chara* wreaking havoc in parts of the Midwest, has star-shaped rhizoids or bulbils that are easily transported and may serve as over-wintering organs. Another invasive exotic, frogbit (*Hydrocharis morsus-ranae*), forms turions on slender stolons that droop down toward the bottom in the fall. They produce a mucilaginous coating and break off and sink, assuring the plant's success the next year.

Hydrilla (*Hydrilla verticillata*) is sometimes known as the "perfect aquatic plant." It has spectacular vegetative growth, and is able to grow quickly under low light and other adverse conditions. Hydrilla produces tubers or subterranean turions on rhizomes and in the leaf axils and in one Florida study, a single turion produced thousands more turions in one season.

Desiccation

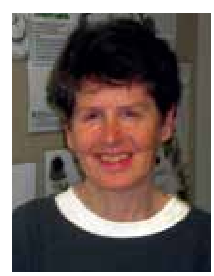
While aquatic plants have many means to survive winter, their Achilles heel is being out of the water. Aside from curly-leaf pondweed turions, which are quite resistant to desiccation, most aquatic plants quickly die when exposed to air. When aquatic plants become a nuisance, and if the water body can be drained, a winter drawdown can effectively kill a large population of plants. The exposed, de-watered lake dries out the plants and kills them by freezing. Different species respond differently to these freezing situations, but this is a tool that may be effective at controlling nuisance levels of plants.

Just as aquatic plants have adapted well to life underwater, so too are they adroit at surviving the winter. The variety of tools for overwintering is in keeping with the multiple adaptations they enlisted for their return to the water from their terrestrial beginnings.

References

Sculthorpe, C.D. 1967. The Biology of Aquatic Vascular Plants. Edward Arnold.

Borman, S., R. Korth and J. Temte. 2014. Through the Looking Glass, 2nd Edition. Wisconsin DNR Publication WY-207-14.



Susan Knight works for the University of Wisconsin-Madison's Center for Limnology at Trout Lake Station and collaborates closely with the Wisconsin Department of Natural Resources. She is involved in many aspects of aquatic plants, including aquatic plant identification workshops and research on aquatic invasive plants. She is especially fond of bladderworts.