

2.14 Duckweed and Watermeal: The World's Smallest Flowering Plants

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Duckweed species can grow so densely on water surfaces that they appear as finely groomed turf. They are considered the world's smallest flowering plants. To put their size and numbers in perspective, watermeal is approximately the size of a sugar crystal or a grain of salt, which translates to 5 to 10 billion plants per acre.

Introduction and spread

Duckweeds represent five genera of small floating aquatic plants in the *Araceae* subfamily *Lemnoideae* (although until recently duckweeds were considered members of the *Lemnaceae* or duckweed family). The duckweeds (*Landoltia*,



Lemna and *Spirodela*), watermeal (*Wolffia*) and bogmat (*Wolffiella*) genera include more than 35 species worldwide; in this chapter, the term “duckweed” will refer to all members of these five genera. Multiple species are native to North America, such as *Spirodela polyrrhiza* (giant duckweed), *Lemna minor* (common duckweed), *Lemna minuta* (least duckweed) and *Lemna gibba* (swollen duckweed), but some species found in the US – including the Australian or Southeast Asian native dotted duckweed (*Landoltia punctata*) – are introduced. Duckweed is widespread in distribution and is found on every continent except Antarctica. Some species, like *Lemna minor*, are native to multiple continents. Growth rates are

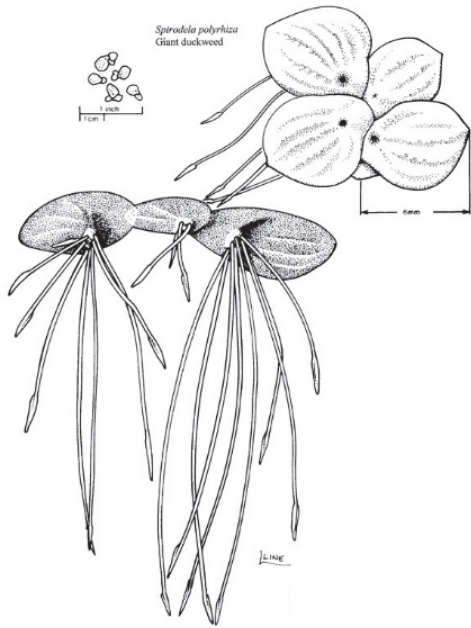
extremely high and populations can double in size in 1 to 3 days under optimal conditions. The diminutive size of duckweed allows plants to easily “hitchhike” on water currents, waterfowl and watercraft, which contributes to its spread.

Although duckweeds are often a nuisance in backyard ponds, the plants are valued and used extensively for applied and basic plant science research. Duckweeds have many potential uses, including biofuel production and as a food source (duckweed reportedly tastes like spinach and is high in protein and vitamins). Duckweeds have also been used as bioremediation agents to remove waterborne nutrients and contaminants. These species can improve water quality in natural systems such as lakes and can reduce nitrogen, phosphorus and metal contamination in commercial waters such as swine-based effluent ponds before they are discharged to other waters, although this could accidentally introduce duckweeds to downstream systems.

Description of species

Duckweeds are monocotyledons and can be distinguished from other floating plants by their small size, which ranges from around a 1/25 of an inch to less than an inch. Duckweeds have the distinction of being the world's smallest flowering plants and some species, especially bogmat and watermeal, are commonly confused with algae. Another

floating aquatic plant that could be confused with duckweed is the native mosquito fern (*Azolla caroliniana*). Mosquito ferns are diminutive like duckweeds but are branched instead of round and plants are often red, particularly when grown in full sun.



Duckweed species can be separated based on: 1) frond size, number and shape, and 2) root structure or lack thereof. Fronds are leaf-like structures and may be modified stem or leaf systems that absorb nutrients from the water column. The function of the modified root structure is not well understood (although the roots may help the plant stay in an upright position), and roots are lacking in the genera *Wolffiella* and *Wolffia*.

The largest duckweeds are up to one inch in diameter and belong to the genus *Spirodela*. Plants in this genus are also the most structurally complex of the duckweeds and have flowers and many roots per frond. Duckweeds in the genus *Landoltia* are similar to *Spirodela* duckweeds, but are smaller (around one third the size), have fewer roots (from several to one per frond) and usually lack the distinctive dot on the frond surface that is characteristic of *Spirodela* species. Duckweeds in the genus *Lemna*, which have one to several fronds and a single root per frond, are smaller than members of the genus *Landoltia*. Plants in the genera *Wolffiella* and *Wolffia* are the smallest of the duckweeds and have the least complex structure (no roots, simplified flowers). These genera can be identified by their fronds, which are long and spindly in *Wolffiella* and oval in *Wolffia*. Although it is fairly easy to

distinguish among the duckweed genera, it is much more challenging to identify species within each genus, particularly in the *Lemna* duckweeds.

Duckweeds are typically found in still, nutrient-rich waters, and populations or colonies of tens of thousands of individual plants can thrive in small pools of water or ditches. Some duckweed species can survive cold (but not freezing) temperatures and increases in salinity can stimulate growth, although excess salinity can inhibit growth or kill plants. Duckweeds can provide habitat for many aquatic organisms such as insects and frogs and can be an important food source for wildlife, including fish and birds (hence the name “duckweed”).

Reproduction

Duckweeds are very productive and might very well be among the fastest growing plants. Despite being the smallest angiosperms, flowers are rarely seen due to size and blooming frequency. The small fruit produced is called a utricle. Duckweed primarily reproduces through asexual vegetative budding where each frond produces a new plant. This mode of growth can allow duckweed to quickly cover ponds and lakes with an extremely short doubling time. Multiple species can produce seeds and turions (or buds) for overwintering; one seed is produced per frond. Turions are modified structures that sink to the bottom of lakes where they overwinter, but not all duckweed species produce them. Seed production is a particularly important adaptation that allows survival of droughts. Seeds are reported to have extremely low survival (if any) after exposure to freezing conditions, which limits overwintering capabilities. However, duckweed seeds and turions are adapted to sink to the bottom of water bodies to escape freezing for insuring a viable propagule bank for growth in warmer conditions.

Problems associated with duckweed

Similar to filamentous algae, duckweed can form dense surface mats that are several layers thick and may include mixtures of different species. However, duckweed’s ability to decrease light penetration and intensity and to consume nutrients can actually inhibit algal growth. Dissolved oxygen concentrations below duckweed mats are often low, which can influence the type and abundance of invertebrate and fish populations. Duckweed mats can also reduce aesthetics and recreational uses of water resources because their excessive growth covers the surface of the water. Duckweed usually causes problems in smaller bodies of water such as backyard ponds, canals, wetlands and other static sites. However, it has also created significant issues on some very large lakes, including Lake Maracaibo in Venezuela (South America’s largest lake).

Management options

Duckweeds can present an extreme challenge to resource managers. Control methods provide only temporary relief; unless every plant is successfully managed, colonies will rapidly re-form because duckweeds reproduce so quickly. In addition, duckweed can survive on mud flats and wet shorelines, which allows them to escape management efforts. These missed plants can quickly re-infest a site once they are flushed back in to the water by wave action or rising water levels. In addition, upstream sources that host colonies of duckweed can also be a source of new introductions.



Spirodela



Landoltia



Lemna



Wolffiella



Wolffia

Floating booms and suction devices can be used to remove duckweed, and rakes can be used when wind and currents cause colonies to accumulate near banks or in isolated small areas (Sections 3.4 and 3.5). However, mechanical harvesting is typically limited to smaller (less than 1/2 acre) water bodies. Dyes do not provide control of duckweed and may actually promote growth of colonies by reducing algal competition. Aeration can relieve the low dissolved oxygen levels associated with large duckweed populations, thus

improving fish habitat, but do not affect plant growth. Grass carp (Section 3.6.2) have been used to manage small infestations of duckweed, although high stocking rates (50 to 75 per acre) of small fish (4 to 6 inches) are needed to have an impact. It is important to remember that small grass carp are very susceptible to predation, so most stocking recommendations specify grass carp that are at least 10 to 12 inch long to reduce predation. However, grass carp that are this large have lost the ability to strain small plants from the water and have little utility for duckweed control.

Chemical control (Section 3.7.1) is the predominant method used to manage duckweed, but different species of duckweeds have differing susceptibilities to herbicides. For example, *Lemna* duckweeds are generally considered easier to control and more susceptible to herbicides than *Wolffia* (watermeal), which are the most difficult species of duckweeds to control. Since these plants often co-exist, it is possible to successfully control one species (*Lemna* duckweed) without causing significant damage to the other (watermeal). Therefore, proper identification of the genera targeted for management is very important. General guidelines for managing *Lemnoideae* species with herbicides are outlined below; however, it is important to remember that effectiveness of control methods are species-dependent and can vary.

There are multiple herbicides that may be used to control duckweed; these are generally separated into slower acting, systemic and faster acting, contact herbicides. These herbicides may be applied in-water (absorbed by the plant primarily from the water column) or to plant foliage (applied directly to the surface of the plant). In-water systemic herbicides are used to manage duckweed when populations cover large areas (or the entire surface) of a water body. These products are relatively easy to apply and, when effective, usually result in long-term control. In-water systemic herbicides can

be applied to the surface of the water or can be injected directly into the water column and need to maintain contact with the plant for an extended period of time. Contact with every individual plant during the application is not required because herbicides applied in-water diffuse through the water column. These herbicides are slower-acting, so large infestations can be treated without negatively affecting dissolved oxygen levels because plant death occurs over an extended period. Fluridone has historically been the most commonly used in-water herbicide for duckweed control, but penoxsulam and bispyribac-sodium are also labeled to control duckweed. The foliar-applied systemic herbicides glyphosate and imazapyr are unlikely to provide long-term control of duckweed because these products become ineffective once they enter the water column and individual plant coverage is insufficient for control.

Depending on conditions and the scale of application, contact herbicides such as diquat and flumioxazin may provide effective control of duckweed. (Note: *Wolffia* duckweeds are generally tolerant of diquat, so foliar applications of diquat alone are not recommended for control of *Wolffia* duckweeds. Foliar applications are also not recommended for *Wolffiella*, although this species is rarely targeted for control.) Other contact herbicides such as chelated coppers are labeled for duckweed control but are not commonly used unless local conditions or water-use restrictions limit other options. Contact herbicides are faster-acting with shorter half-lives in water, so they must be applied to the entire surface area of the duckweed population or as an in-water application to the entire water body, but close to the surface. Surfactants (Section 3.7.3) should not be used when applying faster acting herbicides as a foliar treatment to duckweed because these products can cause plants to “sink”, which washes the herbicide off the leaf surface and reduces efficacy. Foliar treatments that are applied by boat inevitably result in some wash-off as well. Care should be taken to avoid sinking or wash-off during the application process because good coverage is critical when using foliar herbicides. Also, if duckweed colonies are extremely dense, mats might be several layers thick and a foliar application might kill only the plants on the surface of the mat. In this situation, plants in lower layers of the mat are unaffected and can quickly re-colonize the surface of the water. As a result, foliar herbicide applications must often be repeated to control remaining plants that escaped direct exposure to the herbicide during the initial application.

Because contact herbicides act quickly, these products are typically applied to only part of the water body at one time; this helps to avoid the major reduction in dissolved oxygen that can occur when large populations of plants are killed. Some contact herbicides prohibit treating more than one-third to one-half of a water body if dense vegetation is present but allow application of the product to untreated areas 10 to 14 days after the initial application. Contact herbicides should be used as early in the growing season as possible – before peak plant growth and while water temperatures are cooler – to help reduce oxygen depletion.

The first documented case of herbicide resistance (Section 3.7.2) in floating aquatic plants occurred in *Landoltia punctata*; however, this species’ resistance to diquat was reduced when copper was applied in combination with diquat. Using a combination of systemic and contact herbicides (for example, fluridone plus flumioxazin) could improve efficacy and provide longer-term control at lower rates than either product would when applied individually.

Summary

Members of the five duckweed genera are widespread and occur on almost every continent. Despite their diminutive size, these plants can form dense multi-species colonies on the surface of the water, which decreases water quality and impedes recreational and other water resource uses. Duckweeds commonly cause issues in small ponds and canals but are sometimes problematic in larger systems. Mechanical and biological methods are sometimes used for management, but their use is often limited. However, there are several options for chemical control that can be used to manage nuisance colonies of duckweed.

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Page 85: Duckweed infestation; Tyler Koschnick, SePRO Corporation

Page 86: Line drawing; University of Florida Center for Aquatic and Invasive Plants

Page 87: Duckweed montage; Ben Willis, SePRO Corporation

