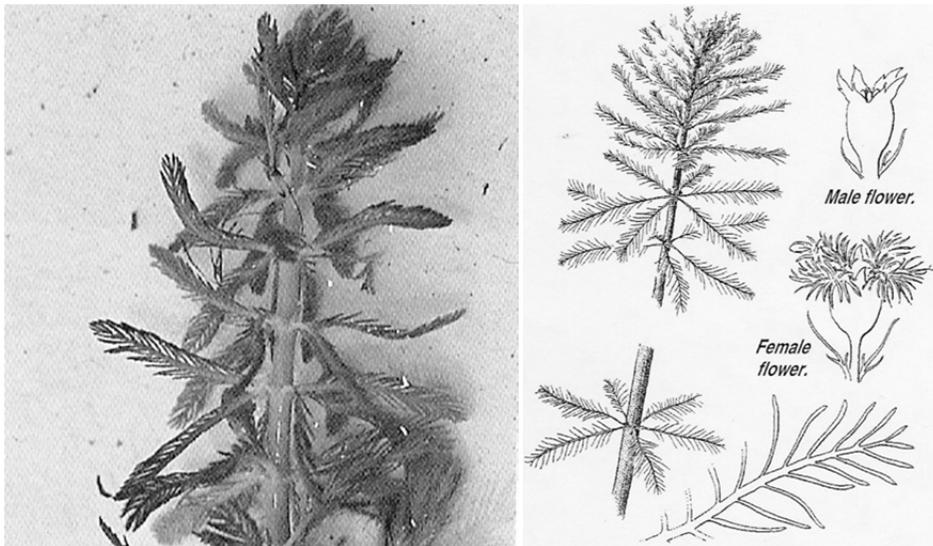


Parrotfeather, *Myriophyllum aquaticum*

Phil Campbell

Fall, 2008



Sources: Westerdahl and Getsinger 1988 (left), Cook 1997 (right)

Classification

Order: Haloragales

Family: Haloragaceae

Genus: *Myriophyllum*

Species: *aquaticum*

Past scientific names

Enydris aquatica Vellozo

M. brasiliense Cambess.

M. proserpinacoides Gillies

Other common names

Parrot's Feather

Brazilian Parrot's Feather

Brazilian Watermilfoil

Thread-of-life

Description

It has both a submerged and emerged structure. The submerged lacks support and is freely swayed by current. The emerged structure is stiff, bright green and can project 20cm above the surface of the water, making it different from other milfoils. Can reach a total of 1.5m in height. It has 4-6 leaves per whorl with each leaf having 18 pairs of segments, resembling a feather (Westerdahl and Getsinger 1988).

Overview

Myriophyllum aquaticum is a dioecious plant native to South America but is now distributed throughout the world: North

America, eastern Australia, western Europe, southern Africa and eastern Asia (Orchard 1981). Its spread has been attributed mainly to its aesthetic value in ponds and aquaria (Orchard 1981). All of its colonies outside the native range are female and spread in a vegetative manner (Bossard et al., 2000). Mechanical means are one of the most common control methods used although this usually results in the spread of *M. aquaticum* because it only takes a small fragment to start a new colony (DiTomaso and Healy 2003). Biological and chemical controls are becoming more widely available including the research of using native fauna to diminish the exotic invader. *M. aquaticum* is a difficult macrophyte to target because it can grow both under water and above water (Bossard et al., 2000) and even on the muddy banks (Guillarmod 1979). It can out-compete native flora, clog drainage ditches, reduce water flow and even increase mosquito larvae abundance (Bossard et al., 2000). Promising controls include utilizing host-specific beetles from the native range of *M. aquaticum* (Cordo and DeLoach 1982, Cilliers 1999b, Solarz and Newman 2001, Oberholzer et al., 2007) and chemical control using 2,4-D has also been shown to be an effective control (Westerdahl and Getsinger 1988).

Origin and Distribution

Parrotfeather occurs naturally throughout most of South America: Brazil, Peru,

Uruguay, Chile and Argentina (Cronk and Fuller 2001) (Fig. 1). The first recorded collection of parrotfeather within the US was near Washington D.C. in 1890 (Bossard et al., 2000). Since then it has been found in southern Africa-1918 (Guillarmod 1979), Japan-1920, New Zealand-1929, Australia-1960s, England-1970s (Bossard et al., 2000), Taiwan-1996 (Yu et al., 2002) and also in a number of other countries around the world: Mexico, Nicaragua, Austria, France, Zimbabwe, Madagascar, Malaysia, Philippines, Java (Orchard 1981), Germany, Spain (Hussner and Losch 2005) and Portugal (Ferreira et al., 1998) (Fig. 1). Except for the northern Midwest states, it can be found in most of the US, including Hawaii, (Orchard 1981). In the northwestern states of the US it can be found in Washington (Fig. 2) (Parsons et al., 2003), Oregon, Idaho, and northern California (DiTomaso and Healy 2003). Within Washington state, parrotfeather is found in most western counties while in eastern Washington it is only found within Yakima County (Parsons et al., 2003) (Fig. 2).

Life-history and Basic Ecology

Myriophyllum aquaticum is a dioecious macrophyte capable of sexually reproducing only where male plants are present, which are currently only known to be in native South America while non-native populations are only female plants (Guillarmod 1979, Orchard 1981, Anderson and Steward 1990, Bossard et al.,

2000). In these areas where only females are found, spread is only vegetative (Guillarmod 1979, Orchard 1981, Bossard et al., 2000). Sexual reproduction consists of unisexual flowers near the base of the leaves; these flowers are generally found from spring to early summer (Orchard 1981) and fruits are never found outside the native range (DiTomaso and Healy 2003). The female-only populations spread by means of fragmentation (Bossard et al., 2000; Weber 2003) or disintegration of a floating *M. aquaticum* mat (Orchard 1981). It is difficult to physically extract all of the portions of parrotfeather because even small fragments can easily settle into mud and begin a new population (Orchard 1981). Guillarmod (1979) and Kane et al. (1991) have all found that these fragments can be as small as 5mm if they contain a node. The whole structure has a thick, waxy protection and possesses tough rhizomes, enabling it to without a fair amount of disturbance and/or traveling (Bossard et al., 2000).

In a survey done in western Germany on the River Erft, Hussner and Losch (2005) found that *M. aquaticum* could survive in a variety of conditions. It was commonly found in areas of low velocity but could still be found in areas of medium to high velocity. In some occurrences it was found to be the dominant macrophyte (Hussner and Losch 2005). The areas where it was found in high velocity, *M. aquaticum* was primarily in submergent form (Hussner and Losch 2005). It can grow down to 1.5m deep

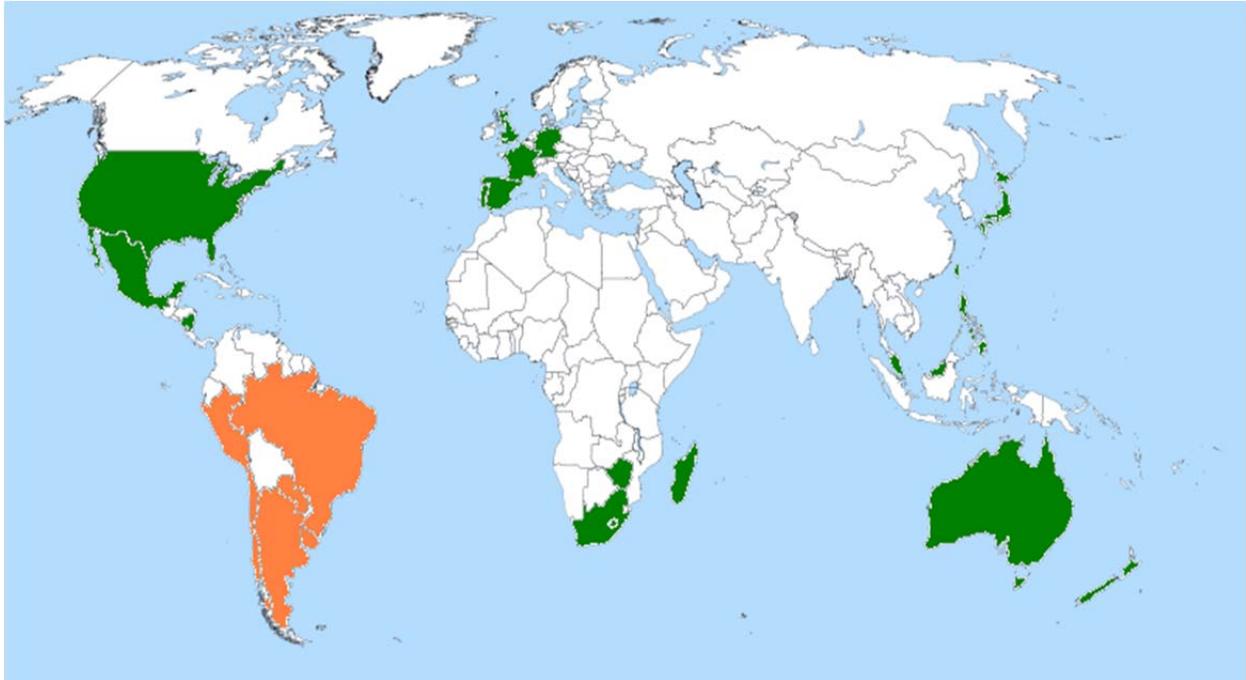


Figure 1. A global distribution of *Myriophyllum aquaticum*. Green denotes non-native occurrences and light red denotes its native range.



Figure 2. *Myriophyllum aquaticum* distribution in Washington state, 2002. (Parsons et al., 2003)

(Cilliers 1999a) and can also grow up onto wet mud banks (Guillarmod 1979, DiTomaso and Healy 2003). *M. aquaticum* is the only emergent milfoil, setting it apart from other milfoils (Westerdahl and Getsinger 1988). This emergent portion never exceeds 24% of its biomass but can contain up to almost 80% of the phosphorus found within a plant (Sytsma and Anderson 1993a). Parrotfeather is found to be phosphorus and carbon limited because it relies on the current uptake of nutrients and has little to no means of storage (Sytsma and Anderson 1993a). Sytsma and Anderson (1993b) found that when the N:P ratio was larger than 8.4, *M. aquaticum* was P-limited and when the ratio was less than 7.8 it was N-limited. In areas with high nutrients, light was the limiting factor for growth (Sytsma and Anderson 1993c). It has an ideal range of pH from 4-9 (Turgut and Fomin 2001, DiTomaso and Healy 2003) and also can do well in water less than 0.5ppt salinity (Stutzenbaker 1999) as well as polluted waters (Cronk and Fuller 2001). During times of freezing temperatures, the emergent tissues usually die off but this dead material insulates enough submerged material for it to come back when it begins to warm up (DiTomaso and Healy 2003). Within its native range, *M. aquaticum* suffers herbivory by several beetle species that exhibit very close host-associations: *Listronotus marginicollis* (Cordo and DeLoach 1982, Oberholzer et al., 2007), *Euhrychiopsis lecontei* (Solarz and Newman 2001) and *Lysathia* n.sp. (Cilliers 1999b). The larvae of these beetles feed

upon the foliage of the parrotfeather plant and burrow inside it to advance to its pupa stage (Cordo and DeLoach 1982, Cilliers 1999b, Solarz and Newman 2001, Oberholzer et al., 2007). Bacterial pathogens have been noticed in some non-native colonies such as *Xanthomonas campestris* (Morris et al., 1999). A fungus, *Pythium carolinianum*, was found in stand of parrotfeather in a California drainage canal (Bernhardt and Duniway 1984).

Invasion Process

The pathway of spread of *Myriophyllum aquaticum* has primarily been for use in fountains (Orchard 1981), ornamental ponds and fish aquaria (Guillarmod 1979, Orchard 1981, Bossard et al., 2000, DiTomaso and Healy 2003). Secondary dispersal has been attributed to hitchhiking on boats, trailers, waterfowl and other wildlife (DiTomaso and Healy 2003). When the mechanism (boat, waterfowl, etc) travels to a different body of water, it can then deposit a fragment of *M. aquaticum*. As mentioned earlier, it takes a piece only 5mm long with a node to begin a new colony (Guillarmod 1979, Kane et al., 1991). Guillarmod (1979) noted that after its introduction to South Africa in 1918, a portion of a parrotfeather colony was taken to a trout hatchery and was then associated with fish-stocked rivers and ponds, furthering its spread. Most of these colonies associated with stocking

fish are still present today (Guillarmod 1979, Oberholzer et al., 2007).

Parrotfeather does well in slow-moving waters and will readily establish and spread in warm temperate and tropical environments (DiTomaso and Healy 2003). Also helping its spread is the load of high nutrients (Sytsma and Anderson 1993c) that run into drainage ditches which is apparent in its widespread distribution in such areas (Bernhardt and Duniway 1984, Bossard et al., 2000). In a site in South Africa, parrotfeather rapidly spread after the removal of water hyacinth (Guillarmod 1979). The physical removal of surrounding aquatic plants somewhat helped parrotfeather because it is able to withstand the disturbance and has less competition after the other species are wiped out (Ferreira et al., 1998, Sabbatini et al., 1998).

Given that *M. aquaticum* can produce dense mats, it is no surprise that only 7% of the light penetrates through the canopy (Sytsma and Anderson 1993c). This severely reduced light not only suffocates the growth of new stalks of *M. aquaticum* (Sytsma and Anderson 1993c) but also hinders growth of any other type of macrophyte (Guillarmod 1979, Stutzenbaker 1999, Weber 2003). Nowhere is there an occurrence of a native species of *Myriophyllum* more abundant than *M. aquaticum* (Guillarmod 1979). The dense mats have effects on other aspects as well, shown by an experiment done by Orr and Resh (1992) in which they found a positive relationship between parrotfeather

stems per square meter and the abundance of mosquito larvae.

Before the widespread searching of chemical means of controlling parrotfeather in South Africa, mechanical methods were used costing thousands of rands (currency in S. Africa, 1USD ~ 1 rand) annually to pay laborers (Guillarmod 1979). Parrotfeather has also disrupted irrigation activities in many of its invaded regions (Cilliers 1999b). In one instance, it caused a red tint in a nearby tobacco farm that utilized an invaded region of water channels, resulting in an almost 50% reduction in the value of the tobacco (Cilliers 1999a and 1999b). Recreation and boat traffic are obstructed by dense mats of parrotfeather (Cilliers 1999a, DiTomaso and Healy 2003); this may result in a decrease of tourism to such areas.

Management Strategies and Control Methods

Myriophyllum aquaticum is not nearly as widespread as *M. spicatum* (DiTomaso and Healy 2003) but still is a worse weed in areas like South Africa (Guillarmod 1979) and New Zealand (Hofstra et al., 2006). South Africa put out the Republic of South Africa Weeds Act in 1964 enlisting all macrophytes within *Myriophyllum* as a noxious weed (Guillarmod 1979). Since then, physical and chemical controls have been applied with minor success and an emphasis on biological controls has been made (Guillarmod 1979, Cilliers 1999b). In New Zealand *M. aquaticum* was legal to sell up until

the introduction of the Biosecurity Act in 1993 (Hofstra et al., 2006). Parrotfeather is also listed on Washington's B list, Wetland and Aquatic Weed Quarantine list and also California's list - CalEPPC: B (DiTomaso and Healy 2003). There has been an ample amount of research in the last two decades to find viable controls of parrotfeather. Its submerged and emerged foliage make it difficult to find successful means of controlling it (Bossard et al., 2000).

In early years of its invasions, parrotfeather was removed by mechanical means (Guillarmod 1979). Sytsma and Anderson (1993a) suggest that the removal of the emergent portions coupled with removal of phosphorus would severely diminish a colony of parrotfeather but this has not been tested and therefore there is no conclusive support to this claim. It became too widespread for physical removal to be successfully effective and other means were sought out. In Washington, mechanical removal lasts for only one growing season (Bossard et al., 2000). Grass carp were experimentally analyzed with some success (Catarino et al., 1997). The younger carp grazed upon more palatable (and sometimes native) macrophytes than the thick stem of the parrotfeather but the older carp were less selective (Catarino et al., 1997).

A recommended control method for parrotfeather is to increase the salinity to lethal levels or to use approved aquatic herbicides (Stutzenbaker 1999). While increased salinity has not been tested, there is an increasing

amount of herbicides allowed for use in aquatic systems. Some such herbicides are listed as an excellent means of control by Westerdahl and Getsinger (1988): 2,4-D; dicamba, diquat and endothall. Acrolein and glyphosate were categorized as fair control (Westerdahl and Getsinger 1988). Gray et al. (2007) experimented with a combination of 2,4-D and canfentrazone-ethyl as well as each one alone. Using outdoor mesocosms, they determined that, at high concentrations, 2,4-D by itself was 100% effective at controlling parrotfeather. If canfentrazone-ethyl or 2,4-D was used alone, there was a likelihood of the colony coming back but if canfentrazone-ethyl was coupled with a small dosage of 2,4-D, it was an excellent control with a low chance of the parrotfeather recovering (Gray et al., 2007). In New Zealand, Hofstra et al. (2006) reports that there are only two products registered for use on submerged weeds: diquat and endothall. Also glyphosate can be used in waters where invasion is possible (Hofstra et al., 2006). In an experiment lasting over the course of year from 1999-2000, Hofstra et al. 2006 cultured parrotfeather and five different herbicides were tested for efficacy of control. Based upon dry weight, they found that triclopyr was the most effective of the treatments. Triclopyr also exhibited selective control on parrotfeather and did little to no harm to non-target species (non-target species recovered in as little as 4 weeks after the treatment) making it a good candidate for the control of *M. aquaticum* (Hofstra et al., 2006).

Another chemical agent, simazine, was found to have a significant difference between the control and a 2-week-old culture in treatments of 0.5 mg/L or higher (Knuteson et al., 1991). Though there was no significant difference between the 4-week-old treatment and control (Knuteson et al., 1991), using simazine directly after a thorough mechanical removal of parrotfeather could possibly be a good control to help eliminate the small fragments.

Biological means of control were also found and subsequently used in experiments. An observed colony of parrotfeather found near Yuba City, CA was seen to be wilted and discolored (Bernhardt and Duniway 1984). The fungus *Pythium carolinianum* was found to be the agent causing the weakening. Bernhardt and Duniway (1984) isolated Ag 23-81-12 from the fungus and used it with some effectiveness at high enough densities to control parrotfeather. Ag 23-81-12 is very difficult to isolate and does not grow fast but does show promise after further researching has been conducted (Bernhardt and Duniway 1984). Other experimental fungal treatments were done using fungi from the neotropics that were seen to have effects on the parrotfeather populations there: *Chaetomella raphigera*, *Cercospora* sp and *Mycosphaerella* sp Barreto et al., 2000). Initial attempts to use these three fungi failed but there is some potential if a means of penetrating the thick waxy stems is found (Barreto et al., 2000). A bacterial infection of parrotfeather was found in 1990 and was identified as *Xanthomonas*

campestris (Morris et al., 1999). This natural infection was only found in 1% of the individual parrotfeather present (Morris et al., 1999). The bacteria was isolated and cultured and Morris et al. (1999) sprayed a plot of the plant with 10^8 colony-forming-units/mL and found a 100% infection rate of the emergent tissues. The emergent structures died off but returned six weeks later because the bacteria did not transpire down the stem into the submergent structure (Morris et al., 1999).

Larger organisms such as beetles were found to devastate *Myriophyllum aquaticum* in its native range and were proceeded to be examined for biocontrol use in invaded areas (Cordo and DeLoach 1982, Cilliers 1999b, Solarz and Newman 2001, Oberholzer et al., 2007). Cordo and DeLoach (1982) collected the weevil, *Listonotus marginicollis*, from *M. aquaticum* plants in the field to test its selectiveness of the plant. Of the 43 plants tested, *M. aquaticum* received the consumption with up to 79% of the stem damaged due to the *L. marginicollis* larvae (Cordo and DeLoach 1982). Similar results were found by Oberholzer et al. (2007) using the same beetle. They collected specimens from Brazil and used only 33 plant species and found *L. marginicollis* to only oviposit and develop upon *M. aquaticum*. Larvae were found to actually burrow down the stem, effectively crossing the emergent/submergent barrier, making this organism an excellent choice for biocontrol of parrotfeather (Oberholzer et al., 2007). Solarz and Newman (2001) did not

experience the same kind of success using *Euhrychiopsis lecontei*, the milfoil weevil, on *M. aquaticum* that Oberholzer et al. (2007) did with their species. They used weevils that had been cultured in lab after hosting on other varieties of *Myriophyllum*. While the female behavior was still to feed and oviposit on *M. aquaticum*, it became apparent that the larvae were physiologically incapable of surviving (100% mortality of larvae) (Solarz and Newman 2001). Cilliers (1999b) surveyed the natural region of parrotfeather in Brazil to find natural enemies of the plant and found the beetle, *Lysathia* n.sp. In laboratory experiments with 32 plant species, this beetle was shown to be host-specific to *M. aquaticum* with the larvae doing most of the damage (Cilliers 1999a). A starter population was released and monitored at a site in South Africa from January 1995 to January 1998 (Cilliers 1999b). *Lysathia* n.sp was found to retard the growth of parrotfeather but it was apparent that a second agent was needed to effectively diminish the weed to acceptable levels (Cilliers 1999b). Less than a year after the release, beetles were discovered up to 50km from the initial site (Cilliers 1999a). After being exposed to the beetle for three years, one site showed a decrease in *M. aquaticum* cover from 50% to 20%. After about a year, the introduced beetle was not without predators (Cilliers 1999a). Two species of *Dorycoris*, a predatory insect, were found by Cilliers (1999a), preying upon adults and larvae of *Lysathia* n.sp in summers of 1996 and 1997. Also after heavy

rains, some *Lysathia* n.sp larvae were infected with a fungus, *Bauveria bassiana* (Cilliers 1999a). The effects of these harmful organisms upon *Lysathia* n.sp are unknown, but a second control agent is still likely to be needed in addition to the beetles' effects on parrotfeather (Cilliers 1999a).

There are also instances of native fauna exhibiting a biotic resistance to the invasive parrotfeather, like that of the North American beaver (Parker et al., 2007). *Myriophyllum aquaticum* biomass was reduced by 90% attributed to beaver herbivory (Parker et al., 2007).

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USDS plant profiles:

<http://plants.usda.gov/java/profile?symbol=MYAQ2>

The Western Aquatic Plant Management Society

<http://www.wapms.org/plants/parrotfeather.html>

Washington Department of Ecology

<http://www.ecy.wa.gov/programs/wq/plants/weeds/aqua003.html>

1999 Locations:

<http://www.ecy.wa.gov/programs/wq/plants/weeds/plocate.html>

Current research and management efforts, and expert contact information in PNW

Current research is ongoing using chemical and biocontrol agents and combinations of the two to eradicate populations of parrotfeather. Management efforts are still in an on-going struggle to find an effective and *safe* way to control it.

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