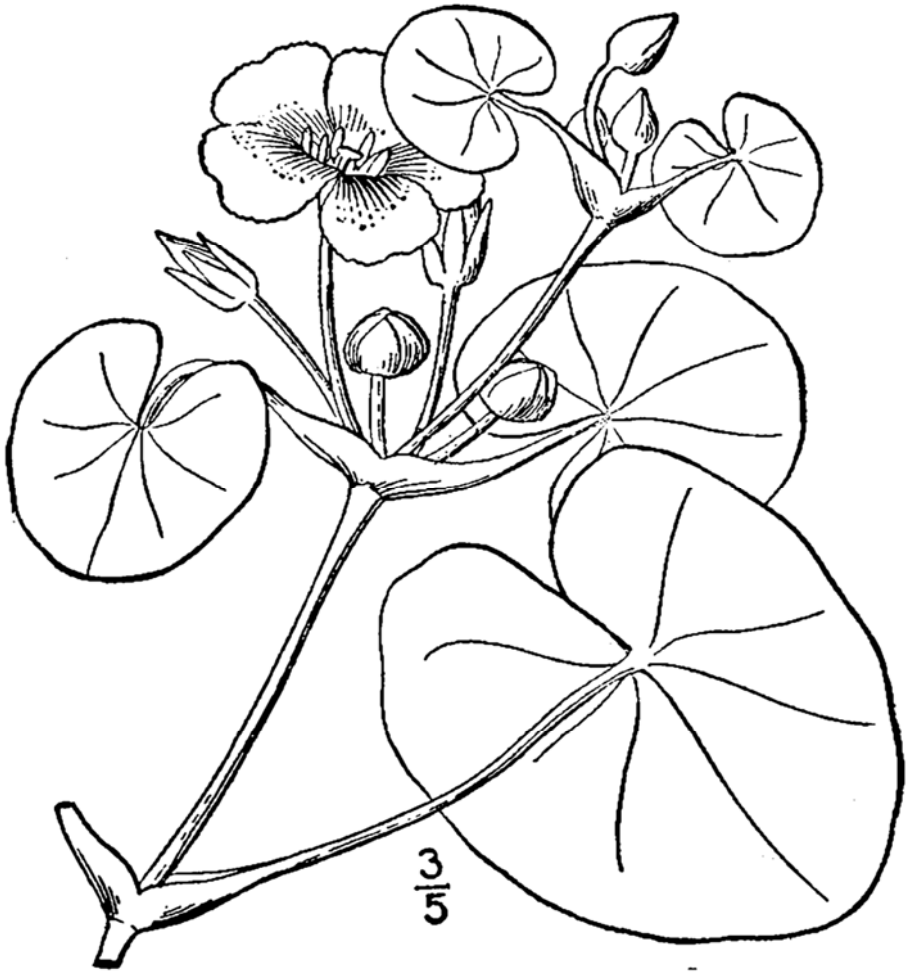
Yellow Floating Heart (*Nymphoides peltata*)

A Technical Review of Distribution, Ecology, Impacts, and Management

May 2009

Michelle E. Nault
Alison Mikulyuk

Document citation:
Nault, M.E. and A. Mikulyuk. 2009. Yellow Floating Heart (*Nymphoides peltata*): A Technical Review of Distribution, Ecology, Impacts, and Management. Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1051 2009. Madison, Wisconsin, USA.



Nymphoides peltata

Cover photo: G.A. Cooper @ USDA-NRCS PLANTS Database

Inside image: USDA-NRCS PLANTS database / Britton and Brown, 1913. An illustrated flora of the northern United States, Canada and the British Possessions. 3:19. Courtesy of Kentucky Native Plant Society. Scanned by Omnitek Inc. Image not copyrighted.

Yellow Floating Heart (*Nymphoides peltata*): A Technical Review of Distribution, Ecology, Impacts, and Management

Michelle E. Nault and Alison Mikulyuk

Bureau of Science Services

This literature review was commissioned by the nonprofit Centre for Agricultural Bioscience International (CAB International; http://www.cabi.org/index.asp) as part of a larger invasive species compendium. We completed eight literature reviews for the project, and due to the large number of requests for this information, we have decided to make the reviews available as DNR miscellaneous publications. Species reviewed include:

- Carolina fanwort (*Cabomba caroliniana*) – [PUB-SS-1047 2009]
- European frog-bit (*Hydrocharis morsus-ranae*) – [PUB-SS-1048 2009]
- Indian swampweed (*Hygrophila polysperma*) – [PUB-SS-1049 2009]
- African elodea (*Lagarosiphon major*) – [PUB-SS-1050 2009]
- Yellow floating heart (*Nymphoides peltata*) – [PUB-SS-1051 2009]
- Curly leaf pondweed (*Potamogeton crispus*) – [PUB-SS-1052 2009]
- Water spangles (*Salvinia minima*) – [PUB-SS-1053 2009]
- Water chestnut (*Trapa natans*) – [PUB-SS-1054 2009]

In completing the literature reviews, we preferentially consulted the peer-reviewed primary literature and supplemented the reviews with secondary sources where necessary. The outline for the reviews is identical for each species and was provided as part of the CAB International commissioning. This effort compliments work conducted during the development of the WDNR's proposed invasive species identification, classification and control rule; a more exhaustive list of species and accompanying literature review summaries can be found on the DNR website at: http://dnr.wi.gov/invasives/

Identity

Taxonomy and Nomenclature

The genus *Nymphoides* (family Menyanthaceae) is generally accepted as containing 39 species (USDA-GRIN, 2004) which occur primarily in tropical and subtropical regions, though also in certain temperate regions of both the Northern and Southern hemispheres (Ornduff, 1966). The genus name comes from the Greek *nympha* meaning 'nymph' and *oides* meaning 'resembling' (IDNR, 2005). *Nymphoides peltata* was first named *Menyanthes nymphoides* by Linnaeus in 1753, revised to *Limnanthemum peltatum* in 1770 by Gmel., and further revised in 1891 to its current accepted scientific name, *Nymphoides peltata* (S.G. Gmel.) Kuntze. *N. peltata* is synonymous with *N. flava* Druce and *N. orbiculata* Druce. *Limnanthemum cordatum* Dunn, described from a specimen collected in northeast Guangdong, China, is probably also synonymous with *N. peltata* (eFloras, 2009). In Europe there are possibly two races, a western European sub-oceanic and a Siberian continental race (Meusel et al., 1978).

The English common names, yellow floating heart and fringed water lily refer to the species' distinctly fringed bright yellow flowers that rise above slightly heart shaped leaves which float on top of the water's surface.

Summary of Invasiveness

N. peltata is an aquatic bottom-rooted perennial plant with floating leaves. It can grow in dense mats and reproduce prolifically through both vegetative and sexual means. The dense mats have caused many negative environmental and economic impacts, including displacing native species, reducing biodiversity, decreasing water quality, impeding recreational activities, and diminishing aesthetic value. *N. peltata* is very difficult to control due to its ability to form a new plant from rhizomes, stolons, separated leaves, or seeds. The dispersal of *N. peltata* to new locations may be aided by the transport of seeds by avian vectors (Cook, 1990); however, the trade and potential escape of *N. peltata* through the water garden industry may play a larger role in its spread (Les and Mehrhoff, 1999). *N. peltata* is considered a noxious weed in New Zealand and parts of North America (NWCB, 2007), and is also declared as invasive in Sweden (Gren et al., 2007) and Ireland (BioChange, 2007). Other species of *Nymphoides* also have the potential to become invasive; *N. indica* and *N. cristata* have been recorded as problematic in Florida.

Distribution, Introduction, and Spread

Distribution

N. peltata is native to Eurasia and the Mediterranean (NWCB, 2007), as well as China, India, and Japan (Mehrhoff et al., 2003). Unlike the majority of *Nymphoides* spp., which mostly occur in the tropics and sub-tropics, *N. peltata* is the only species in the genus occurring in moderately cold temperate areas (Meusel et al., 1978). In Japan, *N. peltata* was once common, but is now listed as a 'vulnerable' species (Environmental Agency of Japan, 2000), and the last remaining population that retains both floral morphs of distyly needed for sexual reproduction is located in Lake Kasumigaura (Takagawa et al., 2006).

N. peltata was introduced to North America during the late 19th century, and has steadily spread and been repeatedly introduced across the United States and in parts of Canada. In Sweden, *N. peltata* was first reported as being introduced in 1870, and has been repeatedly introduced and spread to approximately 40 lakes and rivers (Larson and Willén, 2006). *N. peltata* was relatively recently recorded in New Zealand in 1988 and its establishment is known from only one field site (ENVBOP, 2003). There are also reports that *N. peltata* has been introduced to Ireland (BioChange, 2007). However, the origin of the introduced plant was stated as Brazil (FAO-UN, 2000), which was not found to be part of the native range of *N. peltata* during this review.

History of Introduction and Spread

N. peltata was first recorded in the United States in 1882 in Winchester, Massachusetts. There is also a report of *N. peltata* in New York City's Central Park in 1886. Multiple records from Washington D.C. during the 1890s reported *N. peltata* in several United States Fish Commission ponds as being 'naturalized and spreading into adjacent ponds'. Other first recordings include Missouri in 1893, Louisiana in 1899, and Pennsylvania in 1905. The earliest record of *N. peltata* in the Hudson River was in 1929 from New York, and its origin was speculated as being an escape from a water garden or pool (Stuckey, 1973).

The first records of *N. peltata* in the Midwestern United States were in Ohio in 1930, Indiana in 1945, and Illinois in 1948. In the Southwest, it was recorded in Oklahoma in 1935, and it was believed to have been introduced along with other water plants and fish being transferred into

the lake, though it is also possible that the seeds were introduced to the system by waterfowl (Stuckey, 1973). *N. peltata* was also recorded in the Western U.S in 1930 in Long Lake in Washington (Ornduff, 1963). Records also exist for: Arizona, Arkansas, California, Connecticut, Kentucky, Maryland, Mississippi, New Hampshire, New Jersey, Rhode Island, Tennessee, Texas, and Vermont (USDA-NRCS, 2005). Within the last five years, *N. peltata* has also been recorded in Virginia, Maine, Oregon, and Nebraska (USGS-NAS, 2007).

N. peltata was first recorded as a non-native plant in Sweden in 1870, and it is known to have been intentionally introduced multiple times in the early 19th century (Gren et al., 2007; Hallstan 2005). A single plant released into the River Arbogaån, Sweden in 1933 had spread to cover an area of 0.45km² (111 acres) by 1975 (Löfgren, 1993). Larson and Willén (2006), record 40 lakes and rivers containing *N. peltata* populations, with an overall estimated coverage of approximately 430 km² (106,255 acres) (Gren et al., 2007). *N. peltata* has also been introduced intentionally in Ireland as an ornamental, and its first record was pre-1866 (BioChange, 2007). Between 1987-1999 it was recorded as being present in 10 hectads (1 hectad = 100 km^2 = 24,710 acres).

N. peltata is a relatively recent arrival in New Zealand, and was first recorded in 1988 (NZPCN, 2005). Its population is reported as being localized to only one known field site (ENVBOP, 2003). *N. peltata* is considered a noxious weed in New Zealand and parts of North America (NWCB, 2007), and is also declared as invasive in Sweden (NOBANIS, 2005) and Ireland (BioChange, 2007).

Risk of Introduction

N. peltata had not spread as quickly as other aquatic invasives, but its potential invasiveness should not be overlooked (Les and Mehrhoff, 1999). *N. peltata* is a popular water garden plant, and the ability to order this plant over the internet and through mail order gives it the ability to travel to all parts of the world. It has escaped confinement and has been intentionally introduced on several occasions beyond its native range (Van Dyke, 2005). In the locales where it has been introduced, it has often become the dominant plant species, outcompeting native species and displacing other species which depend on the ecosystem. *N. peltata* has the potential to colonize large areas within one growing season by means of vegetative propagation (Brock et al., 1983), and a single plant can produce over 100 new plants in only 12 weeks (Zhonghua et al., 2007).

Biology and Ecology

Description

N. peltata is an aquatic bottom-rooted perennial plant with round floating leaves, yellow flowers borne upon peduncles arising above the water's surface, and long branching stolons with adventitious roots beneath the water's surface. The circular to slightly heart shaped floating leaves are 3-15 cm (1.2-5.9 inches) in diameter on long stalks that attach to underwater rhizomes. The floating leaves have slight wavy, scalloped margins and are alternately arranged at the stem base but are opposite at apex (eFloras, 2009). They are a green to yellow-green color above, and are often purplish underneath. Each peduncle that rises a few inches above the water's surface can have two to five flowers, which are bright yellow, have five distinctly fringed petals, and are 3-4 cm in diameter. Both long- and short-styled flower morphs are usually needed to sexually reproduce (Ornduff, 1966). The fruit is a 1.2-2.5 cm beaked capsule that contains many flat, smooth, ovular seeds with winged margins. The seeds are approximately 0.4 mm thick, 3.8-5.1 mm long, and 2.7-3.0 mm broad (Cook, 1990).

The winged margins on the seeds help with flotation as well as attachment to avian vectors (Cook, 1990).

Similarities to Other Species
Species in the genus *Nymphoides* look very similar to those in the genus *Nymphaea* (water lilies), but *Nymphoides* have rounded leaf bases unlike the angled leaf bases of *Nymphaea.* In addition, *Nymphoides* produces much smaller flowers which are borne above the water's surface on stalks. There are many other *Nymphoides* species that look very similar to *N. peltata*, and flowers are essential to identify the various species in the genus. *Nymphoides cordata* and *Nymphoides aquatica* are native in the United States, while *Nymphoides indica* and *Nymphoides cristata* are non-native and have been introduced in several locations throughout Florida (Jacono, 2002).

Habitat
N. peltata prefers slow moving rivers, lakes, reservoirs, and ponds; but it can also grow in damp mud, swamps and wetlands. It is also known to occur in ditches, canals, waterways, and "break-through" pools of dikes (Van der Velde, 1979). Backwaters which are influenced by high water of rivers and flooding in the winter are frequently inhabited by *N. peltata* (Van der Voo and Westhoff, 1961). It occurs primarily in eutrophic, alkaline water at depths less than 3.0m (Van der Velde et al., 1979).

Genetics
N. peltata is a hexaploid (x=9) having 2n=54 (Ornduff, 1970). There is a report of 2n=24 from a specimen analyzed by Wang (1940), however multiple reports from diverse locations confirm 2n=54, and the report by Wang needs verification. *N. peltata* has six complete sets of chromosomes in each cell, and its nuclear DNA expressed on a diploid basis is equal to 1.4 pg/2C (BioChange, 2007). In Japan, where *N. peltata* is a listed as a 'vulnerable' species (Environmental Agency of Japan, 2000), research is being conducted on possibly restoring remnant *N. peltata* populations by using the genetic diversity stored in the seed banks in order to reduce inbreeding in the low diversity populations (Uesugi et al., 2007).

Reproductive biology
N. peltata is able to reproduce prolifically by vegetative and sexual means (Larson, 2007). It can reproduce by seeds, stolons, rhizomes, or broken off leaves with part of a stem attached.

Seed production usually requires cross-pollination between the long- and short-styled floral morphs, but self-pollination may result in the formation of small capsules with 10-20 seeds, ¼ the number of seeds usually found in capsules from cross-pollinations. In addition, the seeds from self-pollinated capsules have a lower viability compared with those seeds formed from cross-pollination (Ornduff, 1966). Van der Velde and Van der Heijden (1981) noted 44 insect species which visited flowers during their study, 43 which were species of Hexapoda and 1 species of Aranea. Species of *Apidae*, *Syrphidae*, and *Ephydridae* seem to be the most important in regards to pollination.

The release of developed seeds occurs 32-60 days after the anthesis of the flowers (Van der Velde and Van der Heijden, 1981). Van der Velde and Van der Heijden (1981) also found an average density of 180 fruits/m^2 in natural populations, and a max density of 310 fruits/m^2 in experimental populations. The seeds of *N. peltata* are unable to germinate under hypoxic conditions, and need only a short cold period to overcome their innate dormancy (Smits et al., 1990). *N. peltata* seeds also show a great tolerance with respect to desiccation (Smits et al.,

1989).

Physiology and Phenology
N. peltata flowers from May through October in the United States (USGS-NAS, 2007), and from October through April in New Zealand (NZPCN, 2005). Each flower survives for only one day. Leaf life span lasts from 23-43 days, determined by multiple factors such as exposure to various weather elements, water fluctuations, and substrate (ISSG, 2006). *N. peltata* overwinters as dormant tuberous rhizomes.

Environmental Requirements
N. peltata is a true freshwater species, and does not occur in areas where the average concentration of chlorine rises above approximately 300mg/L. The occurrence of *N. peltata* is restricted to well-buffered alkaline lakes due to the species' requirement of calcium for production of floating leaves (Smits et al., 1992). Maximum probability of occurrence was found at 3.76 meq/L (Smits et al., 1988), equivalent to 188ppm $CaCO_3$. The northern limit of distribution corresponds approximately with the 16°C July isotherm (Van der Velde et al., 1979). *N. peltata* needs ample light and oxygen, and its seeds are unable to germinate under hypoxic conditions (Smits et al., 1990). *N. peltata* grows best on mineral bottoms such as clay (Van der Velde, 1979).

Movement and Dispersal

Natural Dispersal
Hydrochory, the dispersal of seeds by water currents, seems to be the main dispersal mode of seeds within a water body (ISSG, 2006). The flat, slightly hydrophobic seeds are often seen floating on the water's surface in chain-like rafts, loosely connected by the marginal bristles on each individual seed (Cook, 1990).

Vector Transmission
N. peltata seeds have been shown to be completely digested by mallards (*Anas playrhynchos* L.), coots (*Fulica atra* L.), and common carp (*Cyprinus carpio*), adding evidence that endozoochory, the transport of seeds within an animal, does not contribute to successful dispersals between water bodies. However, epizoochory, the transport of seeds externally on animals, has been suggested as a possible dispersal mechanism for movement between isolated water bodies (Smits et al., 1989; Cook, 1990). The unique seed structure of *N. peltata* contains marginal trichomes that readily attach to the feathers and fur of certain waterfowl and mammals. Cook (1990) reported that the flanks, the region between bill and eyes, the webs of the feet, as well as the bill and shield could transport *N. peltata* seeds in waterfowl such as mallards and coots. Cook notes that seeds could also potentially be transported by some amphibious mammals.

Accidental Introduction
N. peltata has been introduced accidently through flooding of ornamental ponds into surrounding natural waterways. It is also possible for *N. peltata* to be a 'hitchhiker' plant, traveling with other species ordered through water garden catalogs.

Intentional Introduction
N. peltata has been repeatedly intentionally planted as an ornamental in different water bodies throughout Sweden and the United States since its first introduction in the late 19th century (Josefsson and Andersson, 2001; Stuckey, 1973). The trade of this plant as an ornamental

through the internet and mail order has greatly increased its availability and ease of spread into new environments.

Natural Enemies
Mallards (*Anas playrhynchos* L.), coots (*Fulica atra* L.), and common carp (*Cyprinus carpio*), have been known to consume and digest the seeds of *N. peltata* in laboratory studies (Smits et al., 1989). Damage to the floating leaves of *N. peltata* caused by the caterpillars of the small china-mark moth (*Cataclysta lemnata*) in the hydrophobous stages has also been observed by Van der Velde (1979). Lammens and Van der Velde (1978) report that a pulmonate snail (*Lymnaea stagnalis*), slug (*Deroceras laeve*), larvae of the brown china-mark moth (*Nausinoe nymphaeata*), and a midge (*Cricotopus trifasciatus*) consume the leaves. Muskrats (*Ondatra zibethicus*) and coots (*Fulica atra*) were also observed consuming the leaves.

Impacts

Economic Impact
Control efforts in Sweden involving the mechanical cutting and removal of *N. peltata* are estimated at costing 28,000 Swedish krona (SEK) (equivalent to $4,500 U.S. or €3,000 EUR) per hectare (1 hectare = 2.47 acres), or 56,000 SEK ($9,000 U.S., €6,000 EUR) annually if the recommended procedure of cutting twice a year is followed (Gren et al., 2007). The loss of recreational and aesthetic value associated with *N. peltata* can also cause a decline in lakefront property values (Robinson, 2004) as well as possible tourism declines.

Social Impact
N. peltata can form dense mats that impede recreational activities such as boating, fishing, swimming, water skiing, canoeing, and kayaking. In addition, unsightly mats of vegetation decrease aesthetic value and alter the ecosystem in which they are present. These declines in recreational and aesthetic values can impact tourism, which can be a major source of livelihood within the community.

Impact on Habitats
N. peltata alters the chemical composition of the water body by increasing the organic content and contributing to internal fertilization by taking up nutrients from the sediment during growth and releasing them back into the water column during decomposition (Josefsson and Andersson, 2001). Where introduced, *N. peltata* can be an excellent competitor for light, and has been known to outcompete native aquatic vegetation and phytoplankton. Dense mats of *N. peltata* also lower the amount of oxygen in the water (NatureServe, 2008).

Impact on Biodiversity
N. peltata reduces biodiversity by competing with and displacing native vegetation, and is capable of changing the fauna and flora of an ecosystem during periods of mass occurrence (Josefsson and Andersson, 2001). *N. peltata* has been shown to exert a strong interspecific interferential effect on the floating leaved water chestnut (*Trapa bispinosa*) (Zhonghua et al., 2007). Larson (2007a) has also shown that one-sided competition from *N. peltata* has a profound effect on the submerged aquatic plant community due to its ability to outcompete submerged vegetation for light.

Management

Economic Value

N. peltata is sold as an ornamental plant for water gardens and ponds, though the specific economic value of this particular species in the ornamental plant trade is unknown.

Social Benefits
None known.

Public Awareness
Several publications have been produced in the United States regarding the impacts of aquatic invasive species such as *N. peltata*, as well as suggested steps that lake recreationists should take to decrease the chance of introducing and spreading aquatic invasives.

Eradication
New Zealand aims to eradicate *N. peltata* from all known sites within 10 years (NWCB, 2007).

Cultural Control and Sanitary Measures
Several regions in the United States have started requiring that recreationists drain all water and clean off all gear (boats, trailers, fishing equipment, etc.) used on water bodies in order to minimize the chance of spreading invasive plants such as *N. peltata* to other areas.

Physical and/or Mechanical Control
Attempts to control *N. peltata* have been very difficult due to its ability to propagate vegetatively through fragments, underwater roots, and rhizomes. Mechanical harvesting only serves as means of creating and introducing more plant fragments, potentially aiding in dispersal to new locations. The leaf petioles are cut by mechanical harvesting, but will re-grow new leaves, requiring one or two cuts each spring and summer to maintain controlled areas (CAPM-CEH, 2004). Both roots and rhizomes are also able to withstand mechanical removal by dredging (Josefsson and Andersson, 2001), and it is too expensive to be considered solely as a method of weed control (CAPM-CEH, 2004). The current cost to mechanically cut and remove *N. peltata* and its fragments is estimated at 28,000 SEK ($4,500 U.S., €3,000 EUR) per hectare, and since it is recommended to be repeated twice a year, annual costs are estimated at 56,000 SEK ($9,000 U.S., €6,000 EUR) per hectare (Gren et al., 2007).

Hand raking can be effective in very small, localized areas where fishing or navigation lanes need to be created (CAPM-CEH, 2004). It may also be possible to alter water depth and flow speeds in channels to make them inhabitable, or cover small areas with opaque floating material (CAPM-CEH, 2004).

Biological Control
None known.

Chemical control
Dichlobenil (Midstream GSR, Casoron G, Luxan dichlobenil) has been effective in controlling *N. peltata* (CAPM-CEH, 2004). A granular treatment is applied in the spring when growth is just beginning, but before the leaves reach the water's surface. In order to assure the chemical is applied evenly over the treated area, motorized or hand operated applicators are recommended. The chemical manufacturers do not recommend treating more than 20% of the water body at one time, nor do they recommend use in waters where flow is greater than 90m/ hour. A combination of mechanical removal of floating leaves mid-summer with subsequent application of dichlobenil has worked in rapid control situations.

Glyphosate has also been used to control *N. peltata*, but it is less effective than dichlobenil and does not give reliable control. Trial studies show that spraying floating leaves between July and September show 40-50% control lasting for one season, while other trials showed recovery towards the end of the season and no long-term control (CAPM-CEH, 2004). In New Zealand, spraying Glyphosate or Penetrant has been reported as effective, though repeated applications may be necessary (ENVBOP, 2003).

Literature Cited

BioChange, 2007. Database of Invasive Plants in Ireland. Dublin, Ireland: Trinity College and Johnstown Castle: Environmental Protection Agency. http://www.biochange.ie/alienplants/result_species.php?species=628&volg=i&lang=latin

Brock TCM, Arts GHP, Goossen ILM, Rutenfrans AHM, 1983. Structure and annual biomass production of *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae). Aquatic Botany, 17:167-188.

CAPM-CEH, 2004. Information Sheet 6: Fringed Waterlily. Centre for Aquatic Plant Management: Center for Ecology & Hydrology. http://www.nerc-wallingford.ac.uk/research/capm/pdf%20files/6%20Fringed%20Water%20Lily.pdf

Cook CDK, 1990. Seed dispersal of *Nymphoides peltata* (S.G. Gmelin) O. Kuntze (Menyanthaceae). Aquatic Botany, 37:325-340.

ENVBOP, 2003. Environment Bay of Plenty Weed Index. Whakatane, New Zealand: Environment Bay of Plenty. http://www.envbop.govt.nz/weeds/Weed224.asp

Environment Agency of Japan, 2000. Threatened wildlife of Japan - Red data book, Vol. 8, Vascular Plants, 2nd ed. Tokyo, Japan: Japan Wildlife Research Center.

eFloras, 2009. Published on the Internet http://www.efloras.org. Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA

FAO-UN, 2000. Introduced Species Fact Sheets: *Nymphoides peltata* introduced to Ireland from Brazil. Rome, Italy: Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations. http://www.fao.org/fishery/introsp/6406/en

Gren I, Isacs L, Carlsson M, 2007. Calculation of costs of alien invasive species in Sweden – technical report. Uppsala, Sweden: Swedish University of Agricultural Sciences.

Hallstan S, 2005. Global warming opens the door for invasive macrophytes in Swedish lakes and streams. Master's Thesis. Uppsala, Sweden: Swedish University of Agricultural Sciences.

IDNR, 2005. Aquatic invasive species: yellow floating heart. Indianapolis, IN: Divison of Fish and Wildlife, Indiana Department of Natural Resources. http://www.in.gov/dnr/fishwild/fish/ais/YELLOW%20FLOATING%20HEART.pdf

ISSG, 2006. Global Invasive Species Database. Invasive Species Specialist Group, IUCN.

Auckland, New Zealand: University of Auckland. http://www.issg.org/database/species/ecology.asp?si=225&fr=1&sts=sss

Jacono C, 2002. Florida's floating hearts: know *Nymphoides*. Gainsville, FL: Florida Integrated Science Center, United States Geological Survey and Center for Aquatic and Invasive Plants, University of Florida. http://fl.biology.usgs.gov/nymphoides.pdf

Josefsson M, Andersson B, 2001. The environmental consequences of alien species in the Swedish Lakes Mälaren, Hjälmaren, Vänern and Vättern. Ambio, 30(8):514-521.

Lammens EHRR, Van der Velde G, 1978. Observations of the decomposition of *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae) with special regard to the leaves. Aquatic Botany, 4:331-346.

Larson D, 2007. Non-indigenous freshwater plants: patterns, processes and risk evaluation . Doctoral Thesis. Uppsala, Sweden: Swedish University of Agricultural Sciences. http://diss-epsilon.slu.se/archive/00001339/01/Non-indigenous_Freshwater_Plants.pdf

Larson D, 2007a. Growth of three submerged plants below different densities of *Nymphoides peltata* (S.G. Geml.) Kuntze. Aquatic Botany, 86:280-284.

Larson D, Willén E, 2006. Non-indigenous and invasive water plants in Sweden (In Swedish with English abstract). Svensk Botanisk Tidskrift, 100:5-15.

Les DH, Mehrhoff LJ, 1999. Introduction of nonindigenous aquatic vascular plants in southern New England: a historical perspective. Biological Invasions, 1:281-300.

Löfgren L, 1993. The Fringed Water-lily in the River Arbogaån 1933-1993. The County of Västmanland Report. (In Swedish).

Mehrhoff LJ, Silander JA, Leicht SA, Mosher ES, Tabak NM, 2003. IPANE: Invasive Plant Atlas of New England. Storrs, CT: Department of Ecology and Evolutionary Biology, University of Connecticut. http://nbii-nin.ciesin.columbia.edu/ipane/

Meusel H, Jäger E, Rauschert S, Weinert E, 1978. Vergleichende Chorologie der zentraleuropäischen. Flora. Bad. 2. Verl. G. Fischer, Jena.

NatureServe, 2008. NatureServe Explorer: An online encyclopedia of life, Version 7.0. Arlington, VA: Nature Serve. http://www.natureserve.org/explorer

NOBANIS, 2005. Regional portal on invasive alien species. North European and Baltic Network on Invasive Alien Species. http://www.nobanis.org/speciesInfo.asp?taxaID=3461

NWCB, 2007. Written Findings of the State Noxious Weed Control Board – Class B – B-Designate Weed: Yellow Floating Heart (*Nymphoides* peltata) (Gmel.) Kuntze). Olympia, WA: Washington State Noxious Weed Control Board. Olympia, USA. http://www.nwcb.wa.gov/weed_info/yfloatingheart.html

NZPCN, 2005. New Zealand Plant Conservation Network. Wellington, New Zealand. http://www.nzpcn.org

Ornduff R, 1963. Northwestern weed notes. Leaflet of Western Botany, 10:30.

Ornduff R, 1966. The origin of dioecism from heterostyly in *Nymphoides* (Menyanthaceae). Evolution, 20(3):309-314.

Ornduff R, 1970. Cytogeography of *Nymphoides* (Menyanthaceae). Taxon, 19(5):715-719.

Robinson M, 2004. Yellow floating heart: an exotic aquatic plant. Boston, MA: Office of Water Resources, Massachusetts Department of Conservation and Recreation http://www.mass.gov/dcr/waterSupply/lakepond/factsheet/Yellow%20Floating%20Heart.pdf

Smits AJM, De Lyon MJH, Van der Velde G, Steentjes PLM, Roelofs JGM, 1988. Distribution of three nymphaeid macrophytes (*Nymphaea alba* L., *Nuphar lutea* (L.) Sm. and *Nymphoides peltata* (Gmel.) O. Kuntze) in relation to alkalinity and uptake of inorganic carbon. Aquatic Botany, 32(1-2):45-62.

Smits AJM, Van Ruremonde R, Van der Velde G, 1989. Seed dispersal of three nymphaeid macrophytes. Aquatic Botany, 35:167-180.

Smits AJM, Van Avesaath PH, Van der Velde G, 1990. Germination requirements and seed banks of some nymphaeid macrophytes: *Nymphaea alba* L., *Nuphar lutea* (L.) Sm. and *Nymphoides peltata* (Gmel.) O. Kuntze. Freshwater Biology, 24:315-326.

Smits AJM, Schmitz GHW, Van der Velde G, 1992. Calcium-Dependent Lamina Production of *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae): Implications for Distribution. Journal of Experimental Botany, 43(9):1273-1281.

Stuckey RL, 1973. The introduction and distribution of *Nymphoides peltatum* (Menyanthaceae) in North America. Bartonia, 42:14-23.

Takagawa S, Washitani I, Uesugi R, Tsumura Y, 2006. Influence of inbreeding depression on a lake population of *Nymphoides peltata* after restoration from the soil seed bank. Conservation Genetics, 7:705-716.

Uesugi R, Nishihiro J, Tsumura Y, Washitani I, 2007. Restoration of genetic diversity from soil seed banks in a threatened aquatic plant, *Nymphoides peltata*. Conservation Genetics, 8:111-121.

USDA-GRIN, 2004. Germplasm Resources Information Network. Beltsville, Maryland, USA: National Germplasm Resources Laboratory. http://www.ars-grin.gov

USDA-NRCS, 2005. The PLANTS Database Version 3.5. Baton Rouge, USA: National Plant Data Center. http://plants.usda.gov

USGS-NAS, 2007. United States Geological Survey – Nonindigenous Aquatic Species. Reston, USA. http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=243

Van der Velde G, 1979. *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae) as a food

plant for *Cataclysta lemnata* (L.) (Lepidoptera, pyralidae). Aquatic Botany, 7:301-304.

Van der Velde G, Giesen, TG, Van der Heijden L, 1979. Structure, biomass and seasonal changes in biomass of *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae), a preliminary study. Aquatic Botany, 7:279-300.

Van der Velde G, Van der Heijden LA, 1981. The floral biology and seed production of *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae). Aquatic Botany, 10:261-293.

Van der Voo EE, Westhoff V, 1961. An autecological study of some limnophytes and helophytes in the area of the large rivers. Wentia, 5:163-258.

Van Dyke JM, 2005. New Invasive Lily, Be on the Look-Out. Aquatics Magazine, 27(3):22. http://www.fapms.org/files/Aquatics/Fall_05_Aquatics.pdf

Wang DT, 1940. Karyokinetic study of *Limnanthemum nymphoides* Hoffmgg. Et Link. Bulletin of the Fan Memorial Institute of Biology, 10(2):113-115.

Zhonghua W, Dan Y, Manghui T, Qiang W, Wen X, 2007. Interference between two floating-leaved aquatic plants: *Nymphoides peltata* and *Trapa bispinosa*. Aquatic Botany, 86:316-320.


© G.A. Cooper