NOBANIS – Invasive Alien Species Fact Sheet

Hydrocotyle ranunculoides

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Species description

Scientific name: *Hydrocotyle ranunculoides* L.f., 1781, Araliaceae (formerly Apiaceae)

Synonyms: *Hydrocotyle natans* Cirillo

Common names: water-pennywort, floating pennywort, floating marsh-pennywort, (Irish) marsh pennywort, greater water pennywort (GB), hydrocotyle flottante, hydrocotyle fausse-renoncule (F), grote waternavel, Amerikaanse waternavel (NL), Großer Wassernabel (DE).

Species identification

H. ranunculoides is an entirely glabrous, stoloniferous, perennial aquatic plant species. Stems float in the water or creep onto the shore and the plants root freely from nodes at about 3-10 cm intervals. The alternate leaves are emergent or floating and sit above the horizontal stem on fleshly petioles of up to 40 cm long. The leaves are non-peltate, suborbicular to reniform with a cordate base, (25) 40 – 100 (180) mm in diameter, and usually broader than long. They are shallowly or deeply incised into 3-7 rounded, crenate or lobulate subequal lobes. The flowers are hermaphrodite, white and grouped by 5 to 10 in a small umbel. The inflorescence is borne on a leafless stalk, 1-6 cm in length and remaining shorter than the petioles. The flowers lack sepals, and have 5 unconnected petals and 5 stamens. The ovary is inferior, two-lobed and has 2 styles. The schizocarp fruits are brownish, nearly round and flat, 2 - 2,5 mm long and 3 - 3,5 mm wide, with faint ribs and divided into two halves, each with a small persistant stalk (Tutin et al. 1968, Martin & Hutchins 1981, Casper & Krausch 1981, Huckle 2002, Hussner & van de Weyer 2004).
Van de Wiel et al. (2009) developed a DNA barcode that discriminates against closely related species.

Fig. 1., 2. and 3. Flowering and fruiting plant (upper left corner), single plant (upper right corner) and a dense stand in a pond (bottom), photos: A. Hussner (1,2), J. Early (3).

Native range
H. ranunculoides is native to North America (USA and British Columbia), Middle America (Martin & Hutchins 1981), South America (Goncalves 1978), Yemen (http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?419736) and Tropical Africa (http://apps.kew.org/efloras/namedetail.do?qry=namelist&flora=fz&taxon=4052&nameid=9686). It is now considered endangered in some northeastern states of the USA (USDA, NCRS 2008). However, there are 19th century EPPO-region records of *H. natans* Cirillo from southern Italy, Palestine and the Caucasus (Tutin et al. 1968, Casper & Krausch 1981), whereas Stoller (1919a, 1919b) describes remains of this species from early Pleistocene interglacial peat in northern Germany. *Hydrocotyle natans* has been synonymized with *H. ranunculoides* or its var. *natans* (Cirillo) Urban (Tutin et al. 1968). The plants reported as invasive in northern Europe are believed to originate from North America.

Alien distribution

History of introduction and geographical spread
H. ranunculoides has become sub-cosmopolitan. Outside its native range, it occurs in Asia (Wood 1997, Iwatsuki 2006) and Australia (Ruiz-Avila & Klemm 1996, Gantes & Caro 2001) and Europe. In Western Europe, it was first reported in the wild from GB in 1990 where it spread rapidly during the following years (Burton 1996, 1998, Newman & Dawson 1999). In Northern Ireland its earliest record was only in 2002 (Down, Antrim; Reynolds 2002) and the number of sites in this country appears to have remained limited so far, with all known sites either eradicated or with control works ongoing or planned (Hackney 2006, (J. Early, pers. comm.)).

The species was introduced in Belgium also at about 1990, but its spread went unnoticed until 1998 (Verloove & Heyneman 1999, Denys et al. 2004). In the Netherlands, the first occurrences of *H. ranunculoides* were reported in 1995 and were also followed by rapid expansion (Baas & Holverda 1996a, 1996b, Baas & Duistermaat 1999, De Mars & Bouman 2002, Pot 2002). Possibly, initial introduction occurred as early as the late nineteen seventies (Jansen 2010). In Germany, *H. ranunculoides* was reported for the first time in 2004 from several water bodies in North Rhine-Westphalia (Hussner & van de Weyer 2004, Hussner et al. 2005). Although the species spread, it remains confined to this region (Hussner & Lösch 2007, Hussner 2007, 2008). Its documented appearance in France dates from about the same time, with records from Corsica, southern France, the region of Paris and close to the Belgian border (Toussaint & Hendoux 2005; Thiébaut 2007). It is also present in Italy, Portugal and Spain (EPPO 2006, EPPO 2009).

Hallstan (2005) describes the risk of future establishment in Sweden, and concludes that this will become more likely as temperatures increase.

Pathways of introduction
The species was distributed by ornamental trade into several countries of the NOBANIS region. *H. ranunculoides* is sold as an ornamental plant and batches of other commercially available aquatic and marsh plants are also easily contaminated with viable fragments. Unintentional introduction often results from dumping excess plants from fish tanks and garden ponds into the wild.

Once introduced, *H. ranunculoides* spreads rapidly in a wide range of conditions. All populations of *H. ranunculoides* in GB most likely originate from a single clone (Newman & Dawson 1999). In lower Belgium, the species initially escaped from a water-treatment experiment and subsequently colonized several water courses by hydrochory. Afterwards it also appeared at many unrelated

locations, presumably from new or secondary introductions. Colonization of isolated water bodies mainly results from discarded plants or intentional planting.

Alien status in region

H. ranunculoides is an alien plant in several NOBANIS countries and is considered invasive in DE, NL, BE, IRE as well as in FR and GB (EPPO 2009).

Country	Not found	Not established	Rare	Local	Common	Very common	Not known
Austria	X						
Belgium				X			
Czech Republic	X						
Denmark	X						
Estonia	X						
European part of Russia	X						
Finland	X						
Faroe Islands	X						
Germany			X				
Greenland	X						
Iceland	X						
Ireland				X			
Latvia	X						
Lithuania	X						
Netherlands				X			
Norway	X						
Poland	X						
Slovakia	X						
Svalbard and Jan Mayen	X						
Sweden	X						

Table 1. The frequency and establishment of *H. ranunculoides*, please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** –The species is not found in the country; **Not established** - The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** - Few sites where it is found in the country; **Local** - Locally abundant, many individuals in some areas of the country; **Common** - Many sites in the country; **Very common** - Many sites and many individuals; **Not known** – No information was available.

So far, all known populations of *H. ranunculoides* in Germany are located in the western and north-western parts of Germany. In the Netherlands, *H. ranunculoides* is considered naturalised and can be found throughout the country, locally causing serious problems (Baas & Duistermaat 1999, Pot 2002). The same holds for Belgium. Here it is well established in the entire Flemish region, as well as in the Brussels region and in part of the Walloon region (Verloove 2006, Adriaens et al. 2009); so far, it does not appear to extend south of the Meuse.

It is expected that *H. ranunculoides* will profit from increasing temperatures in Europe and become more invasive in Central and North Europe (Hussner 2008, Hussner & Lösch 2007). Increased flooding was suggested to facilitate dispersal.

Ecology

Habitat description

H. ranunculoides grows in stagnant and slowly running water. It colonizes the shallow parts and banks of rivers, streams, ditches, mill weirs, ponds, lakes, pits, canals and freshwater marshes. It supports tidal conditions or strong irregular water-level variations and grows on all types of soil, including peat. It even grows on drained soils (Hussner & Meyer, accepted). Once established, it is able to spread into deeper water by forming extensive floating mats. This growth form allows it to cope with frequent water-level changes. It grows best at high-nutrient sites (Newman & Dawson 1999, Baas 2001, Pot 2002), tolerating turbid water and organic pollution. Establishment also occurs on banks which remain barren of any other vegetation. Although highly eutrophic, base-rich sites may be especially susceptible, invasive behaviour also occurs in more nutrient-poor and even acid conditions (de Mars & Bouman 2002). *H. ranunculoides* prefers sunny conditions and reaches maximum photosynthetic rates of up to up to 18 µmol CO_2 m^{-2} s^{-1} at 25–35 °C and a light saturation of ~ 800 µmol photons m^{-2} s^{-1} (Hussner & Lösch 2007).

The species is resistant to central European winters. Frost causes emergent parts to die back, but submerged parts persist. Hussner & Lösch (2007) describe small submerged growth forms of *H. ranunculoides* under a persistent ice cover in a North Rhine-Westphalian stream.

Reproduction and lifecycle

Vegetative growth can be very rapid, with floating mats extending up to 20 cm per day (Newman 2005). Hussner & Lösch (2007) describe the lifecycle of *H. ranunculoides* in Central Europe, where its growth rate is highest in the summer months June and July. Starting from small plants or fragments, plants start growing slowly in spring as soon as the ice melts. Small leaves (up to 10 cm^2) are formed that float on the water surface for the most part (Fig. 4a). With increasing temperature, photoperiod and light intensity, the leaves become larger and reach a height of up to 40 cm above the water (Fig. 4b). The hermaphrodite plants flower and fruit between May and October as the stands get more and more dense. With temperature and light availability decreasing in autumn (Fig. 4c), plants develop smaller fresh leaves. At this time, plants have both floating and submerged leaves (Fig. 4c). Most of the leaves die off as night frosts set in. Floating leaves die when enclosed in ice, but submerged stems and leaves survive the winter (Fig. 4d). From the persisting small submerged plants and leafless stolons, plants grow out again in spring.

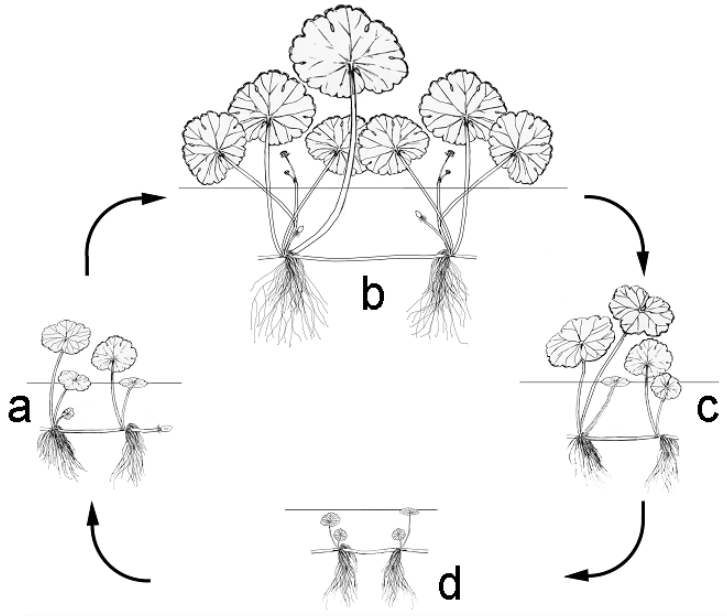

Fig. 4: Life cycle of *Hydrocotyle ranunculoides* (Hussner & Lösch 2007).

Dispersal and spread
Due to the high regeneration capacity of its shoots and fragments (Hussner & Lösch 2007), *H. ranunculoides* can reach new regions very easily by means of waterfowl (Huckle 2002), via water courses and by human intervention. Both intentional, e.g. through the aquatic nursery trade, and unintentional distribution (e.g. by boating) commonly occur. Flooding allows it to become established widely in river valleys. Management activities or water sport activities that result in the fragmentation of plants facilitate dispersal. New shoots are formed even from small stem fragments. Up to 90% of stem fragments 1 cm in length and with only one node, with or without leaves, regenerate within one week; single leaves and internode fragments do not regenerate. Although suggested, dispersal by means of seeds is not yet documented in the region.

Impact

Affected habitats and indigenous organisms
In the EPPO region, *H. ranunculoides* competes with many native plant species. These include littoral marsh plants, such as species of *Carex*, *Juncus*, *Myosotis* and *Rorippa*, as well as submerged aquatic plants. These are overgrown and shaded out by the extensive beds or floating carpets. Species richness of native aquatic plants may be reduced by more than 50% and submerged species may even disappear entirely (Nijs et al. 2009).
Hydrocotyle ranunculoides can cause major problems in nature reserves, recreation areas and intensely managed waterways (EPPO 2009). The floating mats not only affect the penetration of light available for photosynthesis, but also reduce oxygen levels in the water column which can result in fish mortality and influence invertebrate life (EPPO 2009, Stiers et al. 2009). If leading to sediment anoxia, the release of nutrients and potentially toxic substances can be enhanced. Rapid biomass accumulation fuels decomposition processes, alters the composition of the bottom substrate and expedites the infilling of shallow standing waters. In flowing waters, drainage is impeded and siltation increases with heavy infestation.

Genetic effects
There are no genetic effects reported.

Human health effects
There are no known effects on human health.

Economic and societal effects (positive/negative)
Due to its vigorous growth and its propensity for bioaccumulating nutrients (e.g. De Maeseneer 2000) and other substances or enhancing sedimentation, the species has found some uses in water treatment (e.g. Bretsch 2003).

Strongly affected waters lose their attractiveness and safety for recreation (angling, swimming, and boating). Flooding may result from chocked drainage systems and sluices (Tanner 2007); reduced drainage may hinder agricultural activities in the floodplain. Accumulation of heavy metals can make disposal of harvested plant material problematic. Water boards in the Netherlands have spent well over 2 million € in 2007 to control *H. ranunculoides*. In Flanders (Belgium) estimated costs for monitoring and control also amount to several hundred thousands of Euros.

The use of harvested plants as fodder for live stock (Leeflang 2008) or for energy production does not appear to be worthwhile (http://www.invexo.be/nl-

BE/Probleemsoorten/Grote_waternavel/GWNResultaten_2009-2010.aspx, Pot 2008, Wolverton & McDonald 1981).

Management approaches

Prevention methods
In the Netherlands, sale and possession of *H. ranunculoides* is prohibited since 2001 (EPPO 2006) and a covenant with the private sector aims to prevent further distribution. In GB, the Royal Horticultural Society prohibited this plant due to its high invasiveness. Distribution is also prohibited in Switzerland (AFCS 2008). Hussner et al. (2010) recommend including *H. ranunculoides* on the German black list and prohibition of its trade. In Belgium, the species figures on the national black list of invasive species (http://ias.biodiversity.be/ias/species/show/63) and legislation to ban its commercial use and distribution is being prepared (Adriaens et al. 2009). Meanwhile, respresentatives of the sector approved a code of conduct for invasive plants and most wholesalers voluntarily removed *H. ranunculoides* from their catalogue, whilst the ban in the Netherlands also seems to affect commercial availability.

In recognition of the problems caused by *H. ranunculoides* in GB and the Netherlands, the European Plant Protection Organisation, placed the species on the A2 Action list in 2005 and considers it a quarantine pest (EPPO 2006). In addition, EPPO requests for a Pest Risk Analysis (http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRAdocs_plants/05-11897%20PRA%20HYDRA.doc). While recognising the potentially invasive behaviour of *H. ranunculoides*, the EFSA Scientific Panel on Plant Health (EFSA 2007) points out that such behaviour does not occur throughout the region and concludes that the key factors determining invasiveness are insufficiently identified in the Pest Risk Analysis submitted by EPPO (2006) to justify actions at the European Community level. Verbrugge et al. (2012) conclude that the risk classification of *H. ranunculoides* is quite similar among European countries.

As part of the Invasive Species Ireland Project there has been developed a management plan for *H. ranunculoides,* which is available on the ISI website. In terms of the legislation in Northern Ireland *H. ranunculoides* was added to the Wildlife Order (NI) 1985 (as amended) Schedule 9 Part II list which makes it an offence under Article 15 of the legislation for any person to plant it or otherwise cause to grow in the wild (J. Early, pers. comm). *H. ranunculoides* is a Third Schedule Part 1 listed species under the European Communities (Birds and Natural Habitats) Regulations in the Republic of Ireland. Under Regulation 49, it is an offence to plant, disperse, allow or cause to disperse, spread or otherwise cause to grow the plant throughout the state of republic of Ireland (C. O'Flynn, pers. comm.).

Eradication, control and monitoring efforts
There are different experiences in the use of herbicides to control *H. ranunculoides*. Newman & Dawson (1999) describe the effects of glyphosate (2.16 kg ha^{-1} active ingredient) and 2,4-D amine (4.23 kg ha^{-1} active substance) on *H. ranunculoides* in field experiments, when *H. ranunculoides* was most susceptible to 2,4-D amine and resistant to glyphosate. In contrast to that findings, Ruiz-Avila & Klemm (1996) report on a two-step management of *H. ranunculoides*, where mechanical removal of most plants is followed by treatment with Round-up (glyphosate) at an application rate of 360 g ha^{-1}. Chemical treatment followed by spot treatment or mechanical removal is recommended by CAPM (Newman 2005), noting that complete eradication may prove impossible. Newman & Duenas (2010) recommend mechanical removement of as much biomass as possible

followed by intensive hand-picking. Delbart (2011) notes that removal is more difficult and labour intensive for stands that are extensively anchored in mud than for floating carpets and suggests that, at least in some conditions, post treatment during two years may suffice. The effects of hydrogen peroxide treatment and torching were tested on potted plants (van der Burg 2010, van der Burg & Michielsen 2010). In contrast to the former, repeated short burning with a butane torch in early spring or after rigorous removal may be effective to remove stands growing on certain types of embankments. Field testing remains necessary.

In the Netherlands, mechanical control methods are used with varying success to remove *H. ranunculoides* from infested waters. For good results, repeated manual removal of remaining plants afterwards appears necessary.

In Flanders, Belgium, provincial and local authorities collaborate with the Flemish Environment Agency in a monitoring and control programme that addresses both public and private water bodies. The size of reported populations is assessed by trained personnel, followed by control aimed at eradication. This consists of mechanical removal according to a strict protocol, avoiding techniques producing plant fragments, and manual harvesting of all plants remaining after three weeks by a private contractor. Chemical treatment is not allowed. Manual intervention needs to be continued until the site is cleared and efficiency strongly depends on the quality of the work. Consequently, good project management is essential. On private premises, initial removal can be carried out at no expense to the proprietor if prospects for success and follow-up by the land owner are good. Results so far seem promising (Veraart & Soens 2010).

Hussner (2008) describes grazing of non-native *Myocastor coypus* Molina on *H. ranunculoides* stands in North Rhine Westphalia. The animals only eat the leaves, clearing small patches in the dense canopy (Fig. 5). Hussner (2008) also reports infestation by greenflies. Both cannot be considered suitable control agents in the field. Research is being conducted on biological control by weevils (especially *Listronotus elongatus* Hustach) and other potential natural enemies (Gassman et al. 2006, Shaw & Tanner 2008, Sheppard et al. 2006, Newman & Duenas 2010), and some diseases were identified (Newman 2006). The palatability for grass carp, *Ctenopharyngodon idella* (Valienciennes) is not documented (Kempenaar et al. 2008).

Fig. 5. Dense stand of *H. ranunculoides* in North Rhine-Westphalia. Leaves were eaten by non-native *Myocastor coypus*.

Information and awareness
In the Netherlands, a website dedicated to *H. ranunculoides* was created, primarily aimed at water boards and researchers. Information on identification, distribution and control options is presented. Likewise a brochure with general information was produced to inform stakeholders in the management of waterways.

The Belgian Federal services for Public health, Food safety and Environment and the National Biodiversity Platform launched an information campaign on alien species which also focuses on *Hydrocotyle*. The Walloon Ministry of Environment has undertaken similar action. In Flanders, provincial and local authorities raised awareness by distributing free brochures and information sheets among stakeholders, adding warnings to their internet sites, organising information and training sessions and contributing to meetings of professional organisations and interest groups. Several overviews were published in popular and semi-professional journals, and press releases were issued. Overall, response was especially good among nature conservationists, farmers and water managers. A Life+ project started in 2010 to further enhance awareness on invasive plants, focusing in particular on the horticultural curriculum and the development of codes of conduct for professionals (http://www.alterias.be/).

In Germany, three websites provide information on identification, distribution and biology of *H. ranunculoides*.

Knowledge and research
The EFSA Panel (2007) calls for further study of the key factors involved in invasiveness of the species (e.g. abiotic factors, such as eutrophication and channel modification, population dynamics, pathways of dispersal, actual damage).

Within the framework of the EUPHRESCO DeCLAIM project various control methods and the life cycle of *H. ranunculoides* have been studied, including an attempt to adapt the CHARISMA model. This has resulted in a provisional Decision Support System in support of more effective control methods. The DSS consists of field cards to support the identification and assess the degree of infestation, as well as documents for office use to further enhance identification and assist in choosing the best available options for control.

The Interreg IV A project INVEXO (2009-2012; http://www.invexo.be/nl-BE/Home.aspx) aims at dissipating information and stimulating topical research on the control of selected invasive species, among which *H. ranunculoides*, in Flanders and the southern Netherlands.

Recommendations or comments from experts and local communities
See e.g. http://www.ceh.ac.uk/sections/wq/documents/24Hydrocotyleranunculoides_000.pdf.

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Contact persons

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Links

Germany:
www.aquatischeneophyten.de
http://www.floraweb.de/neoflora/handbuch/hydrocotyleranunculoides.html
http://neobiota.naturschutzinformationen-nrw.de/nav3/ArtInfo.aspx?ART=Pflanzen&ID=bbe4026a-5d64-4e8d-b5c5-04c9179b688b

The Netherlands:
http://themas.stowa.nl/Themas/Grote_waternavel.aspx?mID=7216&rID=1152&aID=2030
http://wilde-planten.nl/grote%20waternavel.htm

Belgium: http://ias.biodiversity.be/species/show/63
http://alienplantsbelgium.be/content/hydrocotyle-ranunculoides-0
http://www.fsagx.ac.be/ec/gestioninvasives/Documents/Fiche%E9cologiqueHydrocotyleranunculoidesbis.pdf

GB:
http://www.invasivespeciesscotland.org.uk/invasive_non_native_species/floating_pennywort.asp
http://www.invasivespeciesireland.com/files/public/Management%20contingency/Hydrocotyle.pdf
http://www.ceh.ac.uk/sci_programmes/documents/Hydrocotyleranunculoides.pdf
USA: Department of Agriculture:
http://plants.usda.gov/java/profile?symbol=HYRA
http://www.hear.org/pier/species/hydrocotyle_ranunculoides.htm

EU
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