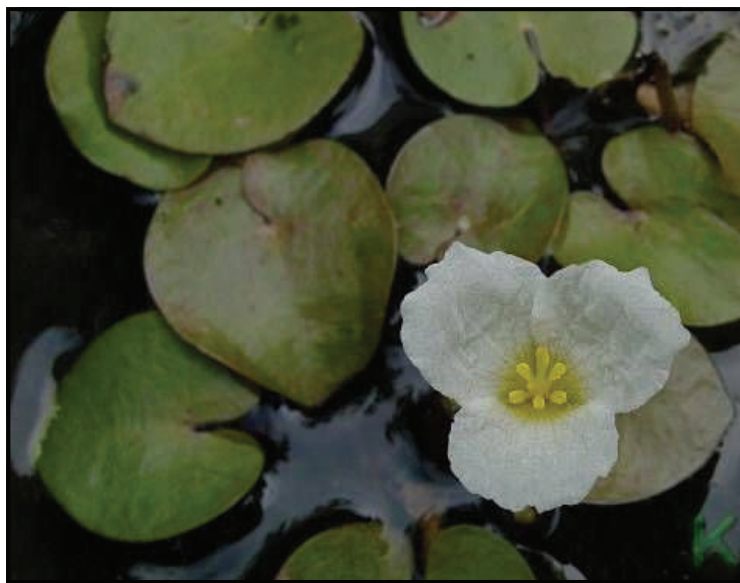


# European Frog-bit (*Hydrocharis morsus-ranae*)

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



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*Hydrocharis morsus-ranae*

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# European Frog-bit (*Hydrocharis morsus-ranae*) 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 *Hydrocharis* (family Hydrocharitaceae) contains 16 accepted species (USDA-GRIN, 2009). The genus name comes from the Greek *hydro* meaning 'water' and *charis* meaning 'some sort of plant'. The specific epithet is derived from the Latin *morsus* meaning 'bite' and *rana* meaning 'frog', referring to the observation of frogs biting at the leaves, searching for caterpillars that make their protective envelopes from the plant (Catling et al., 2003). The English common name 'Frog-bit' comes from this relationship. *Hydrocharis morsus-ranae* was first named by Linnaeus in 1753. This is still its current accepted scientific name.

### Summary of Invasiveness

*H. morsus-ranae* is a free-floating, stoloniferous aquatic plant that can grow to form dense floating mats of interlocking plants which cause many negative environmental and economic impacts. Some of these impacts include displacing native plant species, reducing biodiversity, decreasing water quality and flow, clogging irrigation pumps, impeding recreational activities, and diminishing aesthetic value. *H. morsus-ranae* is extremely difficult and costly to control, and its ability to form new plants vegetatively has allowed it to spread and proliferate quickly

(Scribailo and Posluszny, 1984). The trade and potential escape of *H. morsus-ranae* through the water garden industry plays a large role in its spread to new locations, as does the transportation of this plant on recreational equipment or by wildlife moving between water bodies (Jacono, 2009; Catling et al., 2003). *H. morsus-ranae* is declared a noxious weed in parts of the United States (USDA-GRIN, 2009), and is currently established in New York, Vermont, Michigan, and Washington.

## **Distribution, Introduction, and Spread**

### **Distribution**

*H. morsus-ranae* is native throughout much of Europe and parts of temperate Asia (USDA-GRIN, 2009) as well as Africa (Catling et al., 2003). Cook and Lüönd (1982) define its native range as including western and central Europe, extending from Portugal, western France and the British Isles, north to southern Sweden and Finland, and south to northern Italy. There are scattered records in Eastern Europe to 40°E, and it is sparingly represented in Turkey, the Caucasus and south shore of the Caspian Sea. Isolated populations have also been reported from central Siberia and Kazakhstan (Cook and Lüönd, 1982). Reports of *H. morsus-ranae* from Australia and Japan (Holm et al., 1979) are unreliable and based upon material referable to *Hydrocharis dubia* (Catling et al., 2003). *H. morsus-ranae* has declined or has been extirpated throughout parts of its European range, and is considered a conservation concern in several areas. In the United Kingdom, populations have decreased in their natural habitats, but populations have been reported in canals outside of its native range (Preston and Croft, 1997).

In its non-native range, *H. morsus-ranae* is currently established in southeastern Canada, and it is known primarily from southeastern Ontario and western Quebec. It has also established in northern New York, northern Vermont, and southeastern Michigan in the eastern United States. *H. morsus-ranae* has also recently been reported as established in Washington, and is the first population recorded in the western coast of the United States (Jacono, 2009).

### **History of Introduction and Spread**

The first recorded introduction of *H. morsus-ranae* into Canada was in 1932 when it was intentionally introduced for horticultural purposes at an aquatic pond in the Arboretum of the Central Experimental Farm in Ottawa (White et al., 1993). Earlier introduction of the plant is also possible (Catling and Porebski, 1995). The original plants, or possibly seeds, came from the Zürich Botanical Garden in Switzerland (Dore, 1968; White et al., 1993). The population grew at the original site without incident until 1939, when Minshall (1940) noticed that it had spread to nearby sections of the Rideau Canal and Brown's Inlet, a nearby artificial pond with underwater connections to the Canal. By 1952 a population was collected from the Ottawa River at Montreal Island, either as a result of floating plant material traveling and establishing downstream, or perhaps the result of a separate introduction from specimens which escaped confinement from the Montreal Botanic Garden or McGill University (Minshall and Scarth, 1952; Catling and Dore, 1982; Dore, 1968). In 1953 it had spread towards the exit of the Rideau Canal and along the shores of the Ottawa River. It was found in the main channel of the Rideau River by 1957. During 1960 *H. morsus-ranae* was found at various locations along the Ottawa River around Montreal, as well as much further downstream at Lake St. Peter (White et al., 1993). By 1967 the plant had also spread upstream the Rideau River to at least Merrickville (Dore, 1968), and continued to spread along the Rideau and Ottawa Rivers, as well as into connected tributaries and isolated wetlands (Reddoch, 1976). By 1970 the total extent of North American occurrence was a stretch of 340 km (211 mi) of major waterways

(Catling and Dore, 1982). *H. morsus-ranae* was reported along the Lake Erie shoreline in 1976 (Jacono, 2009). By 1980 it had extended southwest to Lake Ontario and northeast to Quebec City (Catling et al., 2003). *H. morsus-ranae* has continued to spread throughout much of southern Ontario.

*H. morsus-ranae* was first discovered in the United States in 1974 from the Oswegatchie River, just off the St. Lawrence River, in northern New York (Jacono, 2009). By the early 1980s populations had spread and increased at several inland sites south of the St. Lawrence River; by the 1990s it had spread into bays and marshes of Lake Ontario (Catling and Dore, 1982).

*H. morsus-ranae* was first discovered in Vermont during 1993 at the northern portion of Lake Champlain near the town of Grande Isle. By 1999-2000 it had spread to the southern portion of the lake near Benson, Orwell, and West Haven, Vermont, as well as Mill Bay in eastern New York (Jacono, 2009).

In Michigan, unidentified plants were first observed in 1996 during dredging of a slough at Lake St. Clair, and within two years the plants had become abundant throughout the marsh and formed dense mats in cut ponds. In 2000 the plants were identified as *H. morsus-ranae* and established populations were observed in marshes of the Detroit River and Lake St. Clair, both of which flow into Lake Erie (Jacono, 2009).

*H. morsus-ranae* was first discovered in the western coast of the United States in 2001, where an established population was discovered in Snohomish County, Washington, in the wetlands surrounding Meadow Lake (Jacono, 2009; Catling et al., 2003).

### **Risk of Introduction**

*H. morsus-ranae* is continuing to expand its range and become more abundant. *H. morsus-ranae* is a popular water garden and aquarium plant, and the ability to order this plant over the internet and through mail order facilitates its travel to all parts of the world (Catling et al., 2003). It has escaped confinement and has been intentionally or accidentally introduced on several occasions outside of its native range. In the locales to which it has been introduced, it has often become the dominant plant species, outcompeting and displacing native species that depend on the ecosystem (Catling et al., 2003). The ability of *H. morsus-ranae* to reproduce vegetatively facilitates its spread and colonization. It is a highly competitive plant which is capable of a maximum rate of spread of 15.6 km/year (9.7 mi/year), and has already spread over an area of 644 km (400 mi) from point of origin (Catling et al., 2003). Although its initial spread had been confined to interconnected waterways, it has since found ways to spread into isolated and unconnected wetlands and waterways, facilitated by dispersal on boats, trailers, and wildlife (Catling et al., 2003). Within the next 10-20 years, it is anticipated that *H. morsus-ranae* will continue to move westward through the Great Lakes basin towards the Midwest, and become established in the northern Midwest and prairie regions of the United States (Catling and Porebski, 1995; Catling et al., 2003)

### **Biology and Ecology**

#### **Description**

*H. morsus-ranae* is a free-floating stoloniferous herbaceous perennial aquatic plant that can grow to be 0.1-1.5m across, with individual rosettes measuring 1-30 cm (Catling et al., 2003). *H. morsus-ranae* is mostly dioecious, though rarely both sexes can occur on the same rosette (Scribailo and Posluszny, 1984). The roots are usually unbranched, unattached to the

substrate, up to 50 cm long, and change color from green to white as they develop and form numerous long root hairs. The stolons do not readily fragment, though winter buds (turions) are formed on the stolons in autumn, and are ellipsoidal to oval, 5-7 (-9) mm long with a distinct abscission layer. The leathery circular to heart shaped floating leaves are entire, have an indented (cordate) base, and are often dark purple underneath. The floating leaves are 1.2-6 cm long, 1.3-6.3 cm wide, and have a conspicuous aerenchyma on the undersurface near the midvein, with all veins arising from the base. The petioles are slender, 6-14 cm long, with two free lateral stipules up to 2.5 cm long at the petiole base.

The flowers are unisexual, with the male flower arising from a spathe consisting of two bracts, each 1-1.2 cm long on a 0.7-5.5 cm long peduncle. The (1-) 2-5 flowers within each spathe have pedicels up to 4 cm long, white to greenish-white sepals 4-5.5 mm long, and broadly obovate to orbicular white petals 9-19 mm long. Each flower has 9-12 stamens, each 2-3.5 mm long in four whorls, with the two outer whorls being fully fertile, and the inner whorls sterile or partly sterile. The anthers are each 1 mm long, with the pollen approximately 15 Fm (Scribailo and Posluszny, 1984) to 21-39 Fm in diameter (Cook and Lüönd, 1982). The pollen is rounded, radiosymmetric, without apertures, and covered with spines.

The female flowers are borne on peduncles up to 9 cm long, with greenish-white sepals 4-5 mm long, and obovate to orbicular pinkish-white petals 10-15 mm long. The flowers have simple bifurcate or bifid staminodes, and 6 stigmas up to 5 mm long, divided to  $\frac{1}{4}$ - $\frac{2}{3}$  of their length. The seeds are approximately 1 mm long, transversely elliptic, covered with stout blunt processes, each with a spiral pattern on the outer surface (Cook and Lüönd, 1982).

### Similarities to Other Species

*H. morsus-ranae* looks similar to *Limnobium spongia*, commonly referred to as American frog-bit (UFL-IFAS, 2002). *H. morsus-ranae* can be distinguished from *L. spongia* by having relatively less developed aerenchyma on the undersurface of the leaf, relatively longer leaf lobes, leaf veins on either side of the midvein less ascending, free stipules in pairs, roots usually unbranched, and stolon buds developing one instead of multiple roots initially (Catling and Dore, 1982).

*H. morsus-ranae* may also be confused with other round, floating leaves plants such as *Nymphaea* spp., *Nuphar* spp., and *Brasenia schrebii*. *H. morsus-ranae* differs from these aquatics by having rounded leaves with five prominent veins and converging primary veins. *H. morsus-ranae* seedlings may be distinguished from the floating duckweeds *Lemna minor* and *Spirodela polyrhiza* by its roots, which arise from a rosette base or base of a leaf petiole rather than directly from the undersurface of the leaf (Catling et al., 2003).

### Habitat

*H. morsus-ranae* prefers shallow, slow moving waters, inhabiting quiet edges of rivers, lakes, ponds, sheltered bays, open marshes, and wetlands (UFL-IFAS, 2002; Jacono, 2009). It is also found growing in canals, beaver dams, swamps, and irrigation ditches. In its native range, *H. morsus-ranae* tolerates a wide range of climatic conditions, and the genotypes established in North America also appear to have a broad tolerance. It is currently established in two major ecozones and five ecoregions of Canada (Catling et al., 2003). Organic substrate is necessary for development; it does not tolerate waters with a mineral substrate, such as clay pits of fish ponds. *H. morsus-ranae* favors calcium-poor waters, often occurring on peaty soils, and usually in mesotrophic waters rather than oligotrophic conditions (Cook and Lüönd, 1982).

## Genetics

North American populations of *H. morsus-ranae* have a chromosome number of  $2n=28$  as reported by material collected by Dore and analyzed by G.A. Mulligan from the Rideau Canal in Ottawa, Ontario (Catling et al., 2003). Several other authors report  $2n=28$  for Eurasian material (Löve, 1980; Dvorak, 1989). *H. morsus-ranae* possesses one pair of long sub-metacentric chromosomes, the rest being medium length, metacentric, acrocentric, or short metacentric (Cook and Lüönd, 1982). Meiosis is reported to be regular. Dvorak (1989) provides additional information on chromosome morphology.

## Reproductive biology

*H. morsus-ranae* reproduces primarily vegetatively by means of strong stolons and the productions of turion winter buds. It is estimated that a single plant can form approximately 100 to 150 turions (Scribailo and Posluszny, 1984; Dore, 1968). *H. morsus-ranae* also has the ability to reproduce sexually, though reproduction by seeds is rarely reported (Catling et al., 2003), and probably is of limited importance in the spread of the species (Scribailo and Posluszny, 1984). The fruit is a globose berry containing up to 74 seeds, with an average of 26-42 seeds (Scribailo and Posluszny, 1985).

## Physiology and Phenology

In the late summer and early fall, turions are formed along the stolon and then separate from the plant in late fall, sinking towards the bottom where they remain dormant overwinter for 7 months (Dore, 1968). Their release from dormancy requires several weeks of chilling, with a temperature of approximately 5°C being optimal (ISSG, 2005). In the spring the turions rise towards the surface, germinate from late April to early May, and grow into small floating rosettes (Catling et al., 2003). Rosettes are well-developed or fully grown by mid-May. By early June most plants have developed into three rosettes joined by stolons, and by mid to late June will often have six rosettes. Flowering is regulated by photoperiod, though it is very erratic and small fluctuations in temperature can readily influence timing. Generally, the peak flowering period in North America ranges from mid-July to mid-August.

## Associations

*H. morsus-ranae* is often associated with emergent and semi-emergent plants that offer protection from currents, wind, and waves, including: *Typha* spp., *Phragmites australis*, *Sparganium* spp., *Lemna* spp., *Nymphaea* spp., *Hottonia inflata*, *Pontedaria cordata*, *Nuphar variegata*, *Butomus umbellatus*, *Sagittaria* spp., *Equisetum fluviatile*, and *Myriophyllum* spp. (Catling et al., 2003).

In Canada, *H. morsus-ranae* also often occurs with *Potamogeton pusillus*, *Potamogeton vaseyi*, *Spirodela polyrhiza*, *Utricularia vulgaris*, and the exotic *Lythrum salicaria* (purple loosestrife) (White et al., 1993).

## Environmental Requirements

*H. morsus-ranae* is found in waters with pH between 6.5-7.8 (Catling and Dore, 1982). It has been suggested that the mostly acidic, nutrient poor waters of the Canadian Shield and northern Appalachian regions have restricted its spread (Catling and Porebski, 1995). Turions can tolerate only a brief period of freezing conditions, ranging from less than 10 days up to several weeks (Catling et al., 2003).

## **Movement and dispersal**

### **Natural dispersal**

Hydrochory, the dispersal of disseminules by water currents, seems to be the main dispersal mode of vegetative fragments within a watershed.

### **Vector Transmission**

*H. morsus-ranae* can be transported with wildlife and carried to new locations. Dispersal by water birds is suggested as the vector of dispersal of newly discovered populations in Norway (Halvorsen, 1989). Great blue herons (*Ardea herodias*) have been observed flying distances of 2 km (1.2 mi) with interlocking plants of *H. morsus-ranae* attached to their feet (Catling et al., 2003).

### **Accidental Introduction**

*H. morsus-ranae* can be spread accidentally to new locations by the movement of boats, trailers, nets, sea planes, and other recreational equipment between water bodies (Jacono, 2009). Taking plants from an existing wetland in order to restore another wetland may also possibly introduce exotic species to a new location (Catling et al., 2003). *H. morsus-ranae* can also be a 'hitchhiker' plant with other species ordered through water garden catalogs. Plants can also be accidentally introduced to new locations by ornamental ponds flooding into surrounding natural waterways. In addition, it is possible that *H. morsus-ranae* has been introduced through hobbyists emptying unwanted aquarium species directly into surrounding waterways.

### **Intentional Introduction**

The trade of this plant as an aquarium plant through the internet and mail order has greatly increased its availability and ease of spread into new environments. In addition, some new colonies of *H. morsus-ranae* may have been started intentionally by duck hunting clubs, which introduced the plant to provide food and cover for waterfowl (Catling and Dore, 1982).

### **Natural Enemies**

*H. morsus-ranae* is eaten by grass or amur carp (*Ctenopharyngodon idella* Val.), ducks, water birds, and rodents. It is a food plant for a number of insects and water snails (Catling and Dore, 1982), as well as a host to a number of rusts, smuts and molds (Catling et al., 2003). In Europe it is reported as being consumed by beavers (*Castor fiber*) (Catling et al., 2003).

## **Impacts**

### **Economic Impact**

*H. morsus-ranae* impedes water flow in irrigation systems and canals (Catling et al., 2003). In addition, the loss of recreational and aesthetic value associated with *H. morsus-ranae* can cause a decline in waterfront property values, as well as tourism related revenue for the community.

### **Social Impact**

*H. morsus-ranae* can form dense mats that interfere with recreational activities such as boating, fishing, swimming, water skiing, canoeing, and kayaking. In addition, unsightly mats of vegetation decrease aesthetic values. These declines in recreational and aesthetic values can decrease tourism, which can be a major source of livelihood within the community.



### **Impact on Habitat**

The dense floating mats of vegetation that are characteristic of this species can block light penetration in the water column, reducing available light for native aquatic vegetation (Catling et al, 2003). *H. morsus-ranae* can also deplete oxygen levels by limiting water circulation and increasing decomposition of dead plants. Dense mats of *H. morsus-ranae* also have the ability to change water hydrology and quality, negatively affecting the ecosystem in which it occurs.

### **Impact on Biodiversity**

*H. morsus-ranae* reduces biodiversity by competing with and displacing native vegetation, and is capable of changing the fauna and flora of an ecosystem. *H. morsus-ranae* can form dense monocultures which exclude light to native plants and do not provide habitat or food for wildlife. Very dramatic declines in the cover value of native submerged aquatic vegetation were noted under mats of *H. morsus-ranae* (Catling et al., 1988). *H. morsus-ranae* restricts available nutrients and dissolved gases, inhibiting plant growth beneath the mats. Large decomposing mats of *H. morsus-ranae* also have the ability to deplete dissolved oxygen levels, which can potentially cause fish and other aquatic organism kills (Catling et al., 2003).

### **Management**

#### **Economic Value**

Ornamental plants of *H. morsus-ranae* are sold for water ponds, though the specific economic value of this particular species in the ornamental plant trade is undocumented.

*H. morsus-ranae* plant material collected in June had crude protein levels of 22-24%, suggesting a potential value as a forage and compost (Catling et al., 2003).

#### **Social Benefit**

*H. morsus-ranae* has proved beneficial as an experimental plant for physiological and developmental studies because of its large clear unicellular root hairs, ease of cultivation, and regular organogenesis (Catling et al., 2003).

#### **Environmental Services**

*H. morsus-ranae* is a food plant for several species of water birds, rodents, fish, and insects (Catling et al., 2003). In association with other aquatic vegetation, it can provide some cover for insects and fish (Nichols and Shaw, 1986). *H. morsus-ranae* may also be beneficial in removing nitrogen and phosphorus from wastewater (Reddy, 1984).

### **Invasive Species Management**

#### **Prevention**

As with all weed management, prevention is better and more cost-effective than control.

#### **Detection and Inspection Methods**

Infestations of aquatic invasive species are often first reported at boat launches, and these areas should be monitored frequently in order to eradicate or control new invasions at an early stage. Users should inspect all recreational equipment before leaving any water body, and any visible plants, animals, or sediment should be removed. In addition, rinsing gear with hot water or steam may help in removing any additional non-visible organisms.

#### **Rapid Response**

Early detection and eradication are essential in the prevention of future invasions and spread

of *H. morsus-ranae*. Smaller, localized populations are more likely to be controlled successfully than those which have the opportunity to spread and become well-established (Catling et al., 2003).

### **Public Awareness**

Several publications have been produced in areas with *H. morsus-ranae* populations regarding the impacts of invasive species, and the steps that lake recreationists need to take in order to prevent introducing and spreading aquatic invasives.

### **Cultural Control and Sanitary Measures**

In several regions where aquatic invasives are established, governmental organizations 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 aquatic invasive species, such as *H. morsus-ranae*, to other areas.

### **Physical and Mechanical Control**

Past control of *H. morsus-ranae* has been primarily by means of mechanical removal. Small scale raking by hand in the spring can provide a temporary solution, and should be done after overwintering turions have initiated growth on the water surface, but before dense mats have developed (Catling et al., 2003).

In small ponds, *H. morsus-ranae* may be controlled by a water drawdown either overwinter or in late May to early June, when turions have already germinated, but before extensive summer growth has begun (Catling et al., 2003).

### **Movement Control**

Several countries have banned the importation or sale of exotic plants, such as *H. morsus-ranae*, in attempts to minimize the chance of introduction to non-native regions.

### **Biological Control**

Grass carp (*Ctenopharyngodon idella* Val.) will readily feed on *H. morsus-ranae*, though the introduction of grass carp can negatively impact the coexisting native submerged vegetation. In addition, the introduction of grass carp is also prohibited in some countries.

### **Chemical Control**

*H. morsus-ranae* is susceptible to the herbicides Diquat, Paraquat, Chlorthiamid, and Cyanatryn (Newbold, 1977). The first three listed chemicals are most efficient in non-flowing waters, and work to change the plant community structure and reduce species diversity rather than eradicating all plant life. Cyanatryn can be used in flowing water in the form of a slow-release granule. Breakdown of the herbicides in water generally occurs after 2-11 days, depending on bacterial presence and sometimes light (Newbold, 1975; Catling et al., 2003).

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*Hydrocharis morsus-ranae*

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