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Ranunculus sect. *Batrachium* (Ranunculaceae): Contribution to an excursion flora of Austria and the Eastern Alps

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A b s t r a c t : A treatment of *Ranunculus* sect. *Batrachium* is presented for the Eastern Alpine territory as covered by the forthcoming 4th ed. of the "Excursion flora of Austria and the entire Eastern Alps". A newly designed key as well as alternative keys for terrestrial modificants and vegetative specimens are presented. A new outline for the section is applied including (1) the *Ranunculus fluitans* group (*R. fluitans* and *R. pseudofluitans*); (2) the *R. trichophyllus* group (*R. trichophyllus*, *R. confervoides*, and *R. rionii*); (3) the *R. aquatilis* group, including the *R. aquatilis* subgroup with *R. aquatilis* (the only member present in Europe), the *R. peltatus* subgroup (*R. peltatus* and *R. baudotii*) as well as related hybridogenous taxa (*R. penicillatus* s. str.) and (4) *R. circinatus*. The distribution of all species is given for the Austrian federal states, the Bavarian Alps, Liechtenstein and the South Alpine regions of Switzerland, Italy and Slovenia.

K e y w o r d s : *Ranunculus*; *Batrachium*; Austria; Eastern Alps; determination keys; distribution

Z u s a m m e n f a s s u n g : ***Ranunculus* sect. *Batrachium* (Ranunculaceae): Beitrag zu einer Exkursionsflora für Österreich und die Ostalpen**
Ranunculus sect. *Batrachium* wird für den Ostalpenraum vorgestellt, wie er in der geplanten 4. Auflage der "Exkursionsflora für Österreich und die gesamten Ostalpen" abgedeckt werden wird. Ein neu konzipierter Bestimmungsschlüssel sowie ergänzende Teilschlüssel für Landmodifikanten und vegetative Exemplare werden vorgelegt. Ein neuer Gliederungsansatz für diese Sektion wird angewendet, der die folgenden Gruppen ausweist: (1) die *Ranunculus fluitans*-Gruppe, die *R. fluitans* und *R. pseudofluitans* beinhaltet; (2) die *R. trichophyllus*-Gruppe mit *R. trichophyllus*, *R. confervoides*, und *R. rionii*; (3) die *R. aquatilis*-Gruppe, in der zwei Untergruppen zusammengefasst werden, zum einen die *R. aquatilis*-Untergruppe mit *R. aquatilis* als einziger europäischer Art und zum anderen die *R. peltatus*-Untergruppe (*R. peltatus* und *R. baudotii*) sowie zugehörige hybridogene Sippen wie *R. penicillatus* s. str.; und (4) *R. circinatus*. Die Verbreitung aller Arten wird für die österreichischen Bundesländer, den bayrischen Alpenanteil, das Fürstentum Liechtenstein und die südalpinen Regionen der Schweiz, Italiens und Sloweniens dargestellt.

Introduction

For the forthcoming new edition of the Austrian excursion flora (Fischer & al. 2008) covering Austria and the Eastern Alps (Fischer 2015; M. A. Fischer, pers. comm.; referred to as "the territory" here), a critical re-examination of several taxonomically difficult taxa is urgently required.

One of such taxa fraught with identification problems comprises the mainly submergent water crowfoots (*Ranunculus* sect. *Batrachium*). Besides often confusing synonymy, most of these species are challenging, due to their morphological variability, their

often incomplete succession of leaf shape and their tendency towards hybridization, and even formation of hybridogenous species with much better adaptation to changing environments than their parent species. So, it is not surprising that many water crowfoot species have been confused since the beginning of botanical research. Some problems in determination also arise from incomplete material (vegetative, damaged by grazing of water fowl, incomplete leaf shape set present, terrestrial modificants only).

As many other fully aquatic plants (macrophytes), water crowfoot species were always rare in natural landscapes, due to lack of biotopes: most of them need stagnant to moderately running clear waters at moderate depth, with a constant water line and runoff, flooded with plenty of light. Following human habitation, extensive husbandry and the establishment of anthropogenous water courses such as millraces, a lot of new habitats were created where macrophytes could spread. Nowadays, after regulation of water courses, drainage of groundwater ditches in floodplains, intensification of farming, eutrophication of water bodies and increased usage of agrochemicals, a rapid decrease of macrophyte stands and a loss of macrophyte diversity occurred, also affecting water crowfoots.

This paper shall encourage all colleagues in the covered territory to persue fieldwork, to revise herbarium material and thus contribute to a better knowledge of recent and historical distribution of water crowfoot species, recent regional extinctions and re-establishment in revitalized or in any way anthropogenously disturbed water bodies. A set of updated distribution maps for the covered territory and a detailed taxonomic treatment shall be issued together with the new edition of the Austrian excursion flora.

General remarks

New data on molecular phylogenetics and karyotype evolution (Hörandl & al. 2005, Emadzade & al. 2010, 2011, Baltisberger & Hörandl 2016) show that the "*Batrachium* group" is best treated as a section within the genus *Ranunculus* (Ranunculaceae). This section includes white-flowered *Ranunculus* species mainly living in running or stagnant water bodies, some of them facultatively growing as terrestrial modificants on permanently wet sediment surface. These water crowfoots are distributed worldwide, with a centre of diversity in Atlantic Europe. Throughout Europe, 16–18 taxa are present, 10 of them within the territory. In his monographic study, Cook (1966) listed 17 taxa at species rank. As this group is still insufficiently known, approximately 25 taxa are expected in a worldwide view.

The basic chromosome number is $x = 8$ (Baltisberger & Hörandl 2016); di- ($2n = 16$), tetra- ($2n = 32$) and hexaploids ($2n = 48$) are known from the territory.

Due to their stems of high tensile strength (Miler & al. 2014) and leaves of minimized flow resistance, all species are adapted to live even in fast running waters. They develop underwater leaves with laminae reduced to filamentous, terete segments, each containing a vascular bundle.

Hybridization is one of the reasons for misidentifications within the *Batrachium* section. Most of the species may occasionally be involved. The majority of such hybrids is sterile, although flowering, without any fruit setting, and their nature can be recognized only when in flower or at least in bud. Most of these hybrids can be sufficiently described and named in cultivation experiments only. For an overview of their characteristics and their nomenclature see Cook (1966: 183 ff.). Naturally occurring primary hybrids are usually not determinable with certainty, possibly even overseen and ascribed to the morphologically most similar parent species. Important exceptions are:

(1) Primary hybrids between *R. circinatus* (2*x*) and *R. trichophyllus* (4*x*), commonly named as *R.* "×*glueckii*". Despite of Cook's estimation, it is widespread in oxbows of large floodplains, where the parents may coexist, and it is often neglected (frequently confused with *R. circinatus* when in a vegetative state). *R.* "×*glueckii*" can be separated from other sterile hybrids with involvement of *R. trichophyllus*, as it will form only small, atrophied buds, but no receptacles, and its leaves do not completely collapse when taken out of the water.

(2) Primary hybrids of *R. fluitans* (2*x*) with *R. trichophyllus* (4*x*), named *R.* ×*bachii*, but such hybrids, although derived from the same parental species will be of quite different shape, as Cook (1966: 155) himself showed and (1970, 1971) accordantly communicated with H. Vollrath (partially cited in Vollrath & Kohler 1972). They were frequently recorded by Melzers working group (e.g. Meilinger & al. 2005).

Although most of these hybrids are sterile, a few of them are of poor fertility or may show allopolyploidy, thus they may be able to form hybridogenous complexes. Probably all of these complexes are of polyphyletic origin, thus showing a high morphological (and ecological) variability between populations. This fact has contributed to a confusing synonymy, as some (relatively uniform) regional populations were separately named at various ranks. Two such hybridogenous complexes exist in the territory; they are *R. penicillatus* s. str. (on the one hand, showing characteristics of *R. aquatilis*, *R. peltatus*, and *R. trichophyllus*) and *R. pseudofluitans* (on the other hand, mainly showing characteristics of *R. fluitans*). In some populations they may grow together with one or more parental species in the same habitats, occasionally even together in one stand (Englmaier 2014b: 334, fig. 40, 41 and further observations mentioned in this paper).

Except for *R. circinatus* and *R. fluitans*, all of the taxa within this section were traditionally summarized as "*Ranunculus aquatilis* agg." (Meikle 1959, Gutermann & Niklfeld 1973, Englmaier 2008), mainly as a result of widespread confusion between similar, but morphologically and ecologically well separated species occasionally distinguishable even in a vegetative state. Consequently it was splitted into two main groups, the *R. trichophyllus* group and the *R. aquatilis* group, the latter including the *R. aquatilis*-and the *R. peltatus* subgroups besides *R. penicillatus* s. str. as a related hybridogenous taxon (Englmaier 2014a).

Characters used for recognition and determination of species

All characters used for identification and differentiation are discussed in terms of suitability with living as well as herbarium material.

Stems

All species of *Ranunculus* sect. *Batrachium* have submerged (or, with terrestrial modificants, creeping), rhizomatous shoots, rooting in the sediments, with freely floating tips, usually without roots. Stems (and also pedicels and petioles) are continuously growing until reaching their final length (the 4th to 5th internode beneath the apex will have its final length). When internode length shall be compared with pedicel or petiole length, always use the previous internode!

Shoot apices, when broken off, can serve as vegetative propagules and will be occasionally found at the driftline. They may form new roots at their basal nodes.

Rooting at all stem nodes usually indicates stress (mainly anoxic stress in the sediment and thus a decay of rhizomes), so it is intrinsically unsuited for determination. Nevertheless, it can be additionally used to differentiate between fully developed and well-growing *R. trichophyllus* and *R. confervoides*, the latter often growing as a therophyte with only weak roots in the sediment and freewater roots on nearly all nodes.

Foliage

Nearly all species of *Ranunculus* sect. *Batrachium*, including all occurring in the covered territory have capillary underwater leaves, all branched three-fold into 2–3 (*R. fluitans*, *R. pseudofluitans*), 4 (common) or 5, even 6 or more segments (*R. penicillatus* s. str.), thus giving an impression of either long, subparallel filaments in *R. fluitans* (accentuated by its elongated first-order leaf segments, **Fig. 1.1**) or a paintbrush- or tassel-like shape, exceptionally shown by the numerous third-order segments of *R. penicillatus* s. str. (**Fig. 1.4**).

Note that underwater leaves may be slightly variable during seasons, they may be shorter and less branched when growth season ends. Furthermore, some tips of capillary leaves or stipules may be broken off during preparation.

Some species (called homophyllous) only show this underwater type of leaves. These leaves are not able to continue growth when falling dry and their tips will become withered. Some other species (called heterophyllous) occasionally develop a succession of up to three anatomically and morphologically different leaf types: (1) the underwater leaf type as described above, usually collapsing when taken out of the water, rapidly withering, with vestigial stomata, (2) laminate swimming leaves, (3) specialized aerial leaves, shaped like underwater leaves, but with shortened, sometimes slightly flattened, rigid leaf sections, showing fully developed stomata.

Transition leaves may be present, mainly between the capillary underwater type and the laminate swimming type. They may be either a mosaic type (capillary and laminate parts in one leaf, **Fig. 2.2**) or a developing laminate leaf continuing its growth with capillary tips (**Fig. 2.4**).

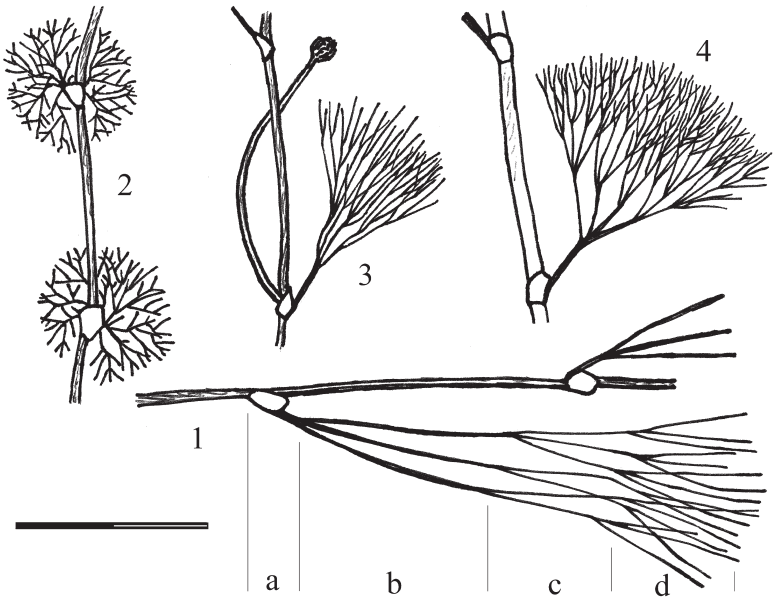


Fig. 1: Underwater leaves of **(1)** *R. fluitans*; **(2)** *R. circinatus*; **(3)** *R. trichophyllus* and **(4)** *R. penicillatus* s. str. **(a)** petiol; **(b)** leaf segments of 1st order; **(c)** leaf segments of 2nd order; **(d)** leaf segments of 3rd order. Scale bar: 50 mm. — **Abb. 1:** Unterwasserblätter von **(1)** *R. fluitans*; **(2)** *R. circinatus*; **(3)** *R. trichophyllus* und **(4)** *R. penicillatus* s. str. **(a)** Blattstiel; **(b)** Blattsegmente 1. Ordnung; **(c)** Blattsegmente 2. Ordnung; **(d)** Blattsegmente 3. Ordnung. Maßstab: 50 mm.

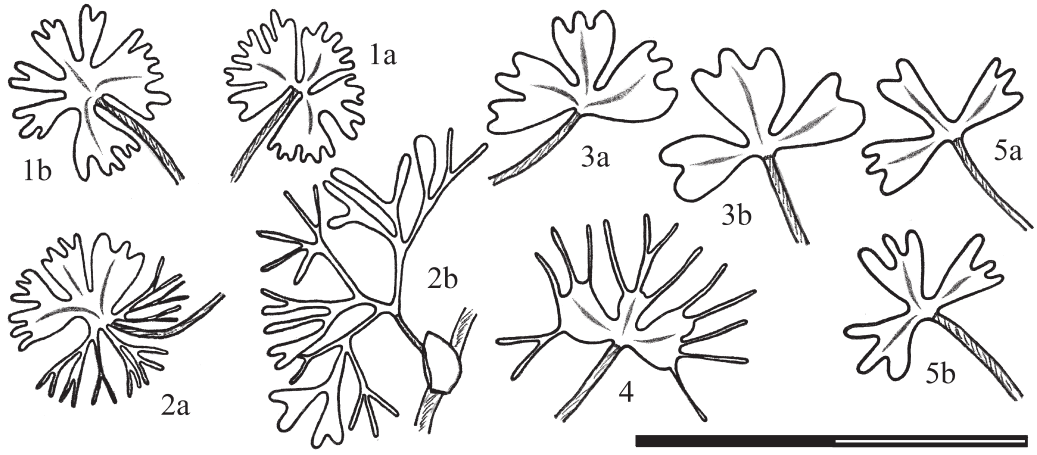


Fig. 2: Swimming leaves of **(1)** *R. aquatilis*; **(2)** *R. aquatilis* transition (mosaic) leaf; **(3)** *R. peltatus*; **(4)** *R. peltatus* transition leaf; **(5)** *R. baudotii*. Scale bar: 50 mm. — **Abb. 2:** Schwimmblätter von **(1)** *R. aquatilis*; **(2)** *R. aquatilis* Übergangs-(Mosaik)-blatt; **(3)** *R. peltatus*; **(4)** *R. peltatus* Übergangsblatt; **(5)** *R. baudotii*. Maßstab: 50 mm.

All heterophyllous species of *Ranunculus* sect. *Batrachium* occasionally remain in a homophyllous state, even when flowering or fruiting. Terrestrial modificants may also continue growth with underwater foliage when flooded, showing that this leaf succession is driven by environmental conditions and not an evolutionary feature as supposed by Cook (1966: 214, fig. 40).

Flowers

Single flowers with long pedicels are formed in the axils of apical leaves. They have the typical shape of *Ranunculus* flowers, mainly with five, sometimes with six or even seven petals. Small-sized flowers are found in the *R. trichophyllus* group, (6)8–12(15) mm in diameter, medium-sized ones in *R. aquatilis* and *R. baudotii*, (12)14–18(20) mm in diameter, and larger ones in all the other species. Note that terrestrial modificants usually have smaller flowers (near the lower diameter limit). Sepals are greenish, usually shorter than petals. Petals are white, of a rather variable shape (most of the species have broad-lanceolate, overlapping petals, the *R. trichophyllus* group and *R. pseudofluitans* may frequently develop narrow lanceolate, not overlapping petals). All petals have a yellow nectar guide and an open nectary near their base. This nectary (nectar pit) is mainly semilunar or semicircular (bowl-shaped) in the *R. trichophyllus* group, circular (cup-shaped) in *R. aquatilis* and pyriform (jug-shaped) in the *R. peltatus* subgroup. It is only well recognizable on fresh material or exceptionally on macrophotos and should be noted on herbarium labels. As it may be variable, especially with the hybridogenous taxa, it is of minor relevance but important with poor material or terrestrial modificants to obtain a determination.

Usually, pedicels are as long as the previous internodes (the previous internode is chosen for comparison, because the following internode may be immature and thus shorter), conspicuously thickened near their base in *R. fluitans* and *R. pseudofluitans*, but fruit peduncles may be somewhat elongated, most prominent (up to 3–4 fold and usually reflexed) in *R. baudotii*.

Fruits

Numerous, (10)15–80(100) single-seeded dry indehiscent fruits (nutlets) are found on a receptacle. They are mainly broad-ovoid, keeled, sometimes bristled, especially along their keel (**Fig. 3.5**), mostly with lateral ribs (**Fig. 3.2–3.6**). Only the nutlets of *R. baudotii* (**Fig. 3.6**) are alate (winged, bearing a small rim at the keel). A short (beak-like) style remnant is either found on the top or at the side of the fruit (in most cases not suited for differentiation).

Receptacles are usually hemispherical, semiovate or even cylindrically elongated in *R. rionii*, *R. baudotii*, and, slightly so in *R. penicillatus* s. str. Receptacle shape is best studied in fruit, when nutlets are already fallen, but can be already seen after flowering, if thoroughly prepared.

Low or missing fruit setting can occur when flowers of insect-pollinated species are flooded as observed by Freyn (1890: 5) with *R. fluitans*.

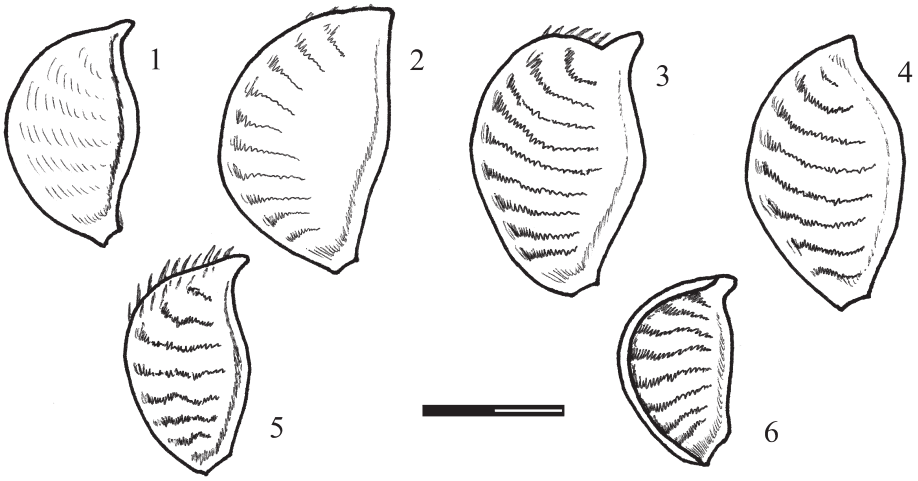


Fig. 3: Nutlets of **(1)** *R. aquatilis*; **(2)** *R. peltatus*; **(3)** *R. penicillatus* s. str.; **(4)** *R. fluitans*; **(5)** *R. trichophyllus* and **(6)** *R. baudotii*. Scale bar: 1 mm. — **Abb. 3:** Nüsschen von **(1)** *R. aquatilis*; **(2)** *R. peltatus*; **(3)** *R. penicillatus* s. str.; **(4)** *R. fluitans*; **(5)** *R. trichophyllus* and **(6)** *R. baudotii*. Maßstab: 1mm.

Water plants generally need highly specialized strategies for dispersal of propagules, either of seeds, fruits or rooting shoot fragments. In running waters, the flow will do this job, together with several animals for short-distance dispersal in the opposite direction. Running as well as stagnant waters will be reached via water fowl, even long-distance dispersal by migrating birds is possible (Naqinezhad & al. 2016 and references cited herein).

Occurrence, distribution and status

Generally, the knowledge of historical and recent distribution of macrophytes is poor, including species of *Ranunculus* sect. *Batrachium*. A lot of records are highly doubtful due to possible confusions, and not all herbarium specimens are determinable with certainty. The known and historical distribution is given here in the style of Fischer & al. (2008), completed with the Bavarian, Swiss, Italian and Slovenian part of the territory, abbreviated as follows:

Austria: **B** (Burgenland), **W** (Vienna), **N** (Lower Austria),
O (Upper Austria), **St** (Styria), **K** (Carinthia) **S** (Salzburg),
Nord**T** (Northern Tyrol), Ost**T** (Eastern Tyrol), **V** (Vorarlberg)
Germany: **BAY** (Bavarian Alps)
Liechtenstein: **FL**
Switzerland: **GR** (Graubünden)

Italy: **Lom** (Lombardy), **TAA** (Trentino-Alto Adige, including **SüdT** [South Tyrol] of Fischer & al. 2008), **Fri** (Friuli-Venezia Giulia)
Slovenia: **SLO**

Every territory sign mentioned in the occurrence chapters indicate at least one confirmed finding. Additional status remarks are [**!**] (new, not reported in Englmaier 2008), [**e**] (expected), [**?**] (doubtful), [**f**] (falsified), [–] (missing: already found in this territory, but no recent findings, suitable biotopes still present), [†] (extinct: no recent findings, no suitable biotopes remaining), [*****] (ephemeral); occasionally these are followed by relevant literature and specimen citations.

Public herbaria mentioned in this contribution are abbreviated according to Index Herbariorum (http://sweetgum.nybg.org/science/ih/).

Guidelines for collecting and preparation of herbarium material

At best, herbarium specimens should include entire rooting shoots with flowers and fruits, together with an occasionally developed terrestrial modificant at the shoreline. Note that even different species can grow together in one single stand. Terrestrial modificants in the vicinity can also represent a different species. If species of the *R. aquatilis* group are suspected, look for specimens with swimming leaves. All foreign matter, e.g. algae, pleustophytic (freely floating or swimming) plants or flotsam should be carefully removed. As possible, try to avoid overlapping of shoots, so to allow observation of branching, internode length and leaf shape. Remove most of the moisture from the plants surface, either by using a wire grid or similar for collecting or dab off water drops with a paper towel. Carefully prepare open flowers. Thoroughly keep all loose parts, and never remove some loose petals, e.g. in *R. trichophyllu*s. Take care of a fast drying process. Occasionally note the shape of the nectaries, especially in terrestrial modificants or in large flowering specimens outside of the *R. aquatilis* group without any swimming leaves (this character is not relevant for determination of fully developed specimens, but can be essential for identification of such incomplete material). If possible take macrophotos of fresh flowers and swimming leaves, and always add a scale.

Keys for determination

Besides a general key for fertile, fully developed material two alternative, experimental keys are presented to enable an informal determination of incomplete (mainly vegetative or incompletely collected) material and terrestrial modificants. Note that nearly all characters are difficult to observe and may be erroneously interpreted. Usually, the general key provides several characters, so, if preventable, do not use only a single character for decision. Tab. 1 gives an overview of all key characters. For additional characters consult

the species description section. As with incomplete material only single or few characters are available, identifications achieved with the experimental keys may be of limited relevance, and further collection of complete material, if possible, is strongly recommended.

I. General key

It is suitable for fully developed specimens with completely foliated shoots, fully flowering and with first ripe fruits. If necessary, plants are to be observed (in the field or under culture), even for a long period to get all the information needed. Note that herbarium specimens are only a snapshot-in-time. Sometimes they may be incomplete (nutlets may be already fallen, even poor fruit setting of allogamous species may occur in late summer) and do not provide all characters needed for determination. In such cases they are determinable only together with other specimens from the same stand. In doing so, it must always be considered, that different species can occur on the same stand, even growing together (for example Englmaier 2014b: 334, fig. 40) or several historical collections may be mixed, as exemplified with *R. pseudofluitans*/*R. penicillatus* s. str. in the vicinity of Brixen (see species descriptions).

Do not attempt to determine incompletely developed or incompletely collected specimens as well as terrestrial modificants using this key – you are guided to specialized keys for a first orientation.

1+ Only vegetative material available ..... **key II**
1– Plants with flowers and/or fruits (if only buds are present, without open flowers or receptacles, a primary hybrid is possible, such as *R.* "×*glueckii*") **2**
2+ Only terrestrial foliage present or the first leaf pair of freshly germinated plants is a laminate type, followed by terrestrial leaves ..... **key III**
2– Mainly (capillary) underwater leaves, sometimes together with (laminate) swimming leaves present (occasionally besides a terrestrial leaf form) **3**
3+ Only capillary underwater leaves (laminate swimming leaves always absent) ... **4**
3– Both capillary underwater leaves and laminate swimming leaves **11**
4+ Receptacle elongated, long-ovoid or cylindrical **5**
4– Receptacle hemispherical, sometimes slightly ovoid **6**
5+ Flowers only 6–12 mm in diameter; sepals more than ½ as long as petals, both never bluish tipped or shaded; pedicels not elongating in fruit; stipules long-ovoid, shorter than 4 mm; nutlets 60–80(100), not alate, with 6–8 ribs ..... ***R. rionii***
5– Flowers more than 12 mm in diameter; sepals less than ½ as long as petals, bluish shaded; petals often bluish tipped; pedicels as long as the internodes when flowering, but 3–4 fold elongated and recurved when fruiting; stipules broad-ovoid, 5 mm long; nutlets 30–60, alate at the keel (**Fig. 3.6**), with 8–12 tenuous ribs ..... ***R. baudotii***
6+ (4) Flowers less than 15 mm in diameter, above the water surface or submerged and then cleistogamous (thus usually full fruit setting); petals deciduous; stamens not more than 20; stipules long-ovoid, small, less than 4 mm long; fruit peduncles not exceeding capillary leaves in length **7**

6– Flowers large, 15 mm or more in diameter, always above the water surface; poor or missing fruit setting with some species; petals persistent during flowering; stamens usually 20 or more; stipules broad-ovoid, 5 mm or more in length; fruit peduncles may be longer than capillary leaves **8**

7+ Capillary leaves (20)30–50 mm long; flowers 8–12(15) mm in diameter; sepals more than ½ as long as the petals; nutlets bristled along the keel, with 5–7 lateral ribs; plant usually not rooting on floating shoots (unless stressed by environmental conditions) ..... ***R. trichophyllus***

Table 1: Overview of key characters. — **Tab. 1:** Merkmalsübersicht.

Ranunculus	growth form	underwater leaves	segments	laminate leaves	stipules	pedicels
trichophyllus	perennial	length < internodes (20)30–50 mm collapsing	4 to 5 equal in length	none	long-ovoid <4 mm	isodiametrical
confervoides	annual/ perennial	length << internodes <20 mm collapsing	3 to 4 equal in length	none	long-ovoid **<3 mm**	isodiametrical
rionii	annual	length < internodes <20 mm collapsing	3 to 4 equal in length	none	long-ovoid <4 mm	isodiametrical
fluitans	perennial	length > internodes 70–200 mm collapsing	2 to 3 **long segments 1st order**	none	broad-ovoid 5–6 mm	**thickened**
pseudofluitans	perennial	length ≥ internodes 60–120 mm collapsing	3 (to 4) **long segments 1st order**	none	broad-ovoid 5–6 mm	**thickened**
penicillatus	perennial	length ≤ internodes 60–120 mm slightly collapsing	4 to 5(6) equal in length	occasional peltatus-type	broad-ovoid 5 mm	isodiametrical
aquatilis	annual/ perennial	length < internodes 20–50 mm collapsing	4 (to 5) equal in length	**frequent aquatilis-type**	broad-ovoid 5 mm	isodiametrical
peltatus	perennial	length < internodes 20–50 mm collapsing	4 (to 5) equal in length	**frequent peltatus-type**	broad-ovoid 5 mm	isodiametrical
baudotii	annual (perennial)	length < internodes 20–50 mm slightly collapsing	4 (to 5) equal in length	occasional peltatus-type	broad-ovoid 5 mm	isodiametrical **elongated**
circinatus	annual/ perennial	length << internodes (10)15–25 mm **not collapsing**	3 (to 5) equal in length	none	elliptical 5 mm	isodiametrical

7– Capillary leaves less than 20 mm long; flowers 6–8 mm in diameter; sepals nearly as long as the petals; nutlets glabrous, with 7–9 lateral ribs; plant regularly rooting on floating shoots ..... ***R. confervoides***

8+ (6) Capillary leaves regularly more than 50 mm in length, longer than the previous internode, 2–3 segments at each branching, 1st order of leaf segments markedly elongated (occasionally even exceeding the internodes length, **Fig. 1.1**); pedicels thickened near the base, especially when fruiting; often low fruit setting **9**

8– Capillary leaves less than 50 mm long, as long as or shorter than the previous

flowers	sepals	petals	nectar pit	stamina	receptacle	nutlets
8–12 (15) mm	>½ petal length attached to petals	small lanceolate **deciduous** not overlapping	semi-circular	10–15	hemispherical pilose fully fruiting	15–30 1.5–1.7 mm bristled
6–8 mm	>¾ petal length attached to petals	small lanceolate **deciduous** not overlapping	semi-circular	8–12	hemispherical pilose fully fruiting	10–18 1.5–1.7 mm ± glabrous
6–12 mm	>¾ petal length attached to petals	small lanceolate **deciduous** not overlapping	semi-circular	12–25	cylindrical pilose fully fruiting	60–80(100) **1–1.4 mm** ± glabrous
18–22 mm	½ petal length slightly deflexed	broad lanceolate persistent overlapping	circular	20–35	hemispherical glabrous **rarely fruiting**	30–40 1.6–2 mm **glabrous**
18–22 (25) mm	½ petal length slightly deflexed	lanceolate persistent ± overlapping	varia-ble	10–40	hemispherical pilose **rarely fruiting**	30–40 1.5–1.8(2) mm ± bristled
(15)18–25 mm	<½ petal length slightly deflexed	broad lanceolate persistent ± overlapping	varia-ble	20–40	hemispherical pilose moderately fruiting	30–50 1.8–2 mm ± bristled
15–20 mm	½ petal length attached to petals	broad lanceolate persistent overlapping	circular	15–25	hemispherical pilose ± fully fruiting	30–40 1.4–1.7 mm ± bristled
(15)18–25(30) mm	<½ petal length attached to petals	broad lanceolate persistent ± overlapping	pyri-form	15–25(30)	hemispherical pilose ± fully fruiting	30–40 1.8–2(2.2) mm ± bristled
(12)15–18(20) mm	<½ petal length slightly deflexed bluish shaded	lanceolate persistent ± overlapping	semi-circular	10–20(25)	ovoid to cylindrical pilose ± fully fruiting	30–60 1–1.4 mm **glabrous, alate**
15–20 mm	½ petal length attached to petals	broad lanceolate persistent ± overlapping	semi-circular	20–25	hemispherical pilose ± fully fruiting	40–50 1.4–1.7 mm bristled

internodes, 3 or more segments at each branching, 1st order of leaf segments not elongated, all orders of leaf segments nearly equal in length (**Fig. 1.2–1.4**); pedicels not thickened, usually (but not always) fully fruiting **10**

9+ Capillary leaves usually exceeding 70 mm in length, up to 3 times longer than previous internodes, 2–3 segments at each branching; occasionally up to 7 petals, usually overlapping; receptacle glabrous ..... ***R.fluitans***

9– Capillary leaves less than 80 mm, (slightly) exceeding previous internodes, usually 3(4) segments at each branching; 5(–6) petals, sometimes not overlapping; receptacle pilose ..... ***R.pseudofluitans***

10+ (8) Capillary leaves much shorter than previous internodes (up to half of internode length, **Fig. 1.2**), not collapsing when taken out of the water (if capillary leaves are longer and not fully collapsing, it may be *R.* "×*glueckii*") ..... ***R. circinatus***

10– Capillary leaves usually more than half as long (up to nearly as long) as previous internodes (**Fig. 1.3**), collapsing when taken out of the water – ***R. aquatilis*** **group** (go to point 11 and ignore swimming leaf characters)

11+ (3) Receptacle elongated, cylindrical; nutlets not exceeding 1.4 mm in length, alate; swimming leaves rarely present, deeply three-lobed (*R. peltatus* type, **Fig. 2.5**), often with extremely slender lobes (see point 5– for further characters) ... . ***R. baudotii***

11– Receptacle hemispherical, sometimes slightly ovoid; nutlets exceeding 1.4 mm in length, not alate **12**

12+ Flowers large, (15)20–22, sometimes exceeding 25 mm in diameter; nectaries slightly to deeply pyriform; nutlets exceeding 1.7 mm in length, with distinct lateral ribs (**Fig. 3.2–3.3**); swimming leaf shape semicircular, deeply three-lobed, usually only one secondary lobe (*R. peltatus* type, **Fig. 2.3**), transition leaves (laminate leaves continue apical growing like capillary leaves, **Fig. 2.4**) rarely present ... **13**
(note that *R. penicillatus* s. str., dependent on its origin, is extremely variable in flower size: if flowers smaller than 20 mm, petals with (slightly) pyriform nectaries and laminate leaves missing or rare, of *R. peltatus* type, go to point 13–)

12– Flowers smaller, usually around 15–18(20) mm in diameter; nectaries semicircular to circular, never pyriform; nutlets not exceeding 1.7 mm, indistinctly ribbed (**Fig. 3.1**); swimming leaf shape circular, deeply dissected, more than one secondary lobe (**Fig. 2.1**), transition leaves (mosaic type, **Fig. 2.2**) often present ..... ***R. aquatilis***

13+ Nectaries deeply pyriform; stamens not more than 25; laminate (swimming) leaves always present when fully developed; underwater leaves usually shorter than 50 mm, regularly branched in 4 segments, fully collapsing when taken out of the water ..... ***R. peltatus***

13– Nectaries slightly pyriform (rarely circular); stamens 20–40; laminate (swimming) leaves rarely present; underwater leaves of variable length, sometimes up to 60 mm long, often branched in 5 or more segments, especially of 3rd order (**Fig. 1.4**), sometimes only partially collapsing when taken out of the water .... ***R. penicillatus*** **s. str.**

II. Key for vegetative specimens
Results are only for orientation and fully developed plants must be re-examined!

1+ Laminate (swimming) leaves present (swimming leaf shape alone can only be used for orientation, but not for a reliable result of determination) …… **key I, point 11**

1– Only underwater leaves present …… **2**
2+ Underwater leaves exceeding (or at least equalling) previous (fully elongated) internodes in length, 2–3 segments at each branching, 1st order of leaf segments elongated (**Fig. 1.1**) …… ***R. fluitans* group**
2– Underwater leaves shorter than previous fully elongated internodes, regularly (3)4 or more segments at each branching, all leaf segments nearly equal in length (**Fig. 1.2–1.4**) …… **3**
3+ Stipules long-ovate, fairly inconspicuous, less than 4 mm long …… ***R. trichophyllus* group**
3– Stipules broad-ovate, conspicuous, 5 mm or more in length …… **4**
4+ Leaves remaining spread (not collapsing) when taken out of the water (occasionally *R.* "×*glueckii*") …… ***R. circinatus***
4– Leaves collapsing when taken out of the water …… ***R. aquatilis* group**

III. Key for terrestrial modificants
Some non-flowering/fruiting plants freshly germinated on wet surfaces may lack all other leaf types, thus they are not suitable for any further identification. In all other cases results may be uncertain, such plants should be recollected and examined in a fully developed stage.

Note that flowers of terrestrial modificants may be much smaller than those of aquatic plants, pedicels and peduncles may be shorter than usual. Nevertheless, *R. rionii*, for example, can be still separated from *R. aquatilis* group-species. Nectary shape, receptacle shape, fruit shape and occasionally peduncle length (*R. baudotii*) may allow some determinations, but always keep in mind, that only a single differential character will never give a reliable result.

1+ Laminate leaves present (occasionally only as a basal pair of leaves when freshly germinated)…… **key I point 11**
1– Laminate leaves absent…… **2**
2+ Receptacle conspicuously elongated, long-ovoid or cylindrical …… **3**
2– Receptacle hemispherical or only slightly ovoid …… **4**
3+ Flowers 6–8(12) mm in diameter; petals deciduous; nutlets not alate (frequently occurring as a terrestrial modificant) …… ***R. rionii***
3– Flowers 12–15 mm in diameter; petals persistent; nutlets (**Fig. 3.6**) alate at the keel (rarely occurring as a terrestrial modificant)…… ***R. baudotii***
4+ (2) Flowers small, 8–12 mm; petals deciduous; stamens 10–15; tips of terrestrial

leaves usually withered (no anatomically different terrestrial leaf type present, but underwater leaves adapted to terrestrial life)..... ***R. trichophyllus***

4– Flowers large, exceeding 12 mm; petals persistent during flowering; stamens 15–30; tips of terrestrial capillary leaves usually well rounded, leaf segment tips not withered **5**

5+ Flowers (12)15–18 mm in diameter; nectaries circular; nutlets 1.4–1.7 mm long, indistinctly ribbed (**Fig. 3.1**) ..... ***R. aquatilis***

5– Flowers 15–20(25) mm in diameter; nectaries generally (but sometimes shallowly) pyriform; nutlets longer than 1.7 mm, distinctly ribbed (**Fig. 3.2–3.3**)..... **6**

6+ Nectaries deeply pyriform; stamens 15–25..... ***R. peltatus***

6– Nectaries slightly pyriform to circular; stamens 20–40 (both species may occur as terrestrial modificants, nearly inseparable in this state: sepals adhering to the petals may indicate *R. penicillatus* s. str., while *R. pseudofluitans* may have deflexed sepals ..... ***R. penicillatus* s. str.** or ***R. pseudofluitans***

Overview and classification approach

Ranunculus sect. *Batrachium* is characterized by a highly dynamical evolution including recent hybridization and speciation processes. As comprehensive studies in molecular phylogenetics are missing and available data are of low resolution, a new morphologically based classification is applied here, it includes:

– *R. fluitans* group (*R. fluitans*, *R. pseudofluitans*)
– *R. trichophyllus* group (*R. trichophyllus*, *R. confervoides*, *R. rionii*)
– *R. aquatilis* group, including the *R. aquatilis* subgroup (*R. aquatilis*), the *R. peltatus* subgroup (*R. peltatus*, *R. baudotii*) as well as *R. penicillatus* s. str.
– *R. circinatus.*

Ranunculus sect. *Batrachium*

Ranunculus fluitans group (*R. fluitans*, *R. pseudofluitans*)

Large plants with long shoot tips floating in fast running waters, up to 2 m deep. Plants are strictly homophyllous, capillary underwater leaves are branched three-fold into only two or three segments usually with the first-order segments the longest (and much longer than the petioles, **Fig. 1.1**). Flowers large (up to 25 mm in diameter) above the water surface, flower- and fruit peduncle thickened. Usually low fruit setting.

(1) *Ranunculus fluitans* (*Batrachium fluitans*, *R. fluviatilis*, *R. peucedanifolius*)

Description: *Ranunculus fluitans* is a perennial herb, hibernating with rhizomes and shoots in the water body near the substrate surface. Hibernating leaves are usually short and dark green. During the vegetation period the floating shoots grow up to 5 m or more in length, with typical elongated, bright green leaves. Shoots are rarely rooting at the nodes. It does not tolerate drought periods (Schratt-Ehrendorfer 1999: tab. 19). It will die back when temporarily falling dry, and grow up from its rhizomes when submerged again.

It is strictly homophyllous, has only underwater leaves with filamentous segments, from 70 up to 200 mm long, branched three-fold, at each branch divided into 2–3 subparallel floating segments (**Fig. 1.1**), the first-order (the lowest) segments markedly exceeding all others in length, sometimes even the internode. Leaves are always longer than internodes of fully elongated shoots. Stipules are broad-ovoid, 5–6 mm long.

Pedicels are shorter than their bracts and up to as long as the previous internodes, conspicuously thickened (mainly near the base), not recurved and not markedly elongated in fruit. Flowers are 18–22 mm in diameter, with 20–35 stamens, emergent, allogamous and sensitive to submersion (then lacking any fruit setting, as already observed by Freyn 1890). Sepals are half as long as petals, slightly reflexed. As the only indigenous species, *R. fluitans* will occasionally have up to 7 petals. These are broadly lanceolate, usually (but not in all cases!) overlapping, persistent, their nectaries are deeply circular. Receptacles are hemispherical, usually completely glabrous (occasionally a few single hairs), with up to 40 nutlets (when fully fruiting). Nutlets are glabrous, keeled, 1.6–2.0 mm long with 8–10 lateral ribs and a small style remnant nearby the top (**Fig. 3.4**).

Ranunculus fluitans is diploid [2*n* = 16, Germany: Donaueschingen and Great Britain: Quorndon, Derbyshire (Cook 1962); Poland (Turała 1969)]. Tetraploids (2*n* = 32) are mainly confused with *R. pseudofluitans*; triploid counts may indicate primary hybrids, as C. D. K. Cook (1970, 1971) accordantly communicated with H. Vollrath (cited in Vollrath & Kohler 1972).

Habitat: *Ranunculus fluitans* is usually found in fast running softwater rivers with gravelly or sandy bedload, low bedload transport and relatively low runoff diversity. So it is mainly distributed in low mountain ranges with silicaceous bedrocks.

Occurrence within the territory: W [*: Schratt-Ehrendorfer 1999: 108], **N, O, St** [Englmaier 2015], **K** [†: bei Gurk, 19th century, leg. E. Josch, correctly recognized by Murmann, WU 074490], **S** [– Flachgau, bei Elixhausen, 19th century, leg. F. P. Storch, SZB 33720; Grödig/Gartenau, 28. 5. 1995, leg. S. Ellmauthaler, SZB 30024], Nord**T** [**?**], **V** [**?**], **BAY** [**?**: records in creeks along the Alpine foothills are all doubtful, may be either hybrids (Cook 1966: 153 in river Würm/Starnberger See) or *R. pseudofluitans* (Sonnberger 2012, 2013)], **Lom** [**?**], **TAA** [†: Bozen, 19th century, leg. J. Zallinger, LI 395101].

(2) *Ranunculus pseudofluitans* (*R. peltatus* var. *pseudofluitans*, *R. penicillatus* subsp. *pseudofluitans*, *R. calcareus*, *R. penicillatus* s. lat. p. p.)

Cook (1966: 156) summarized taxa of hybridogenous origin under *R. penicillatus* (s. lat.) and quoted *R. pseudofluitans* as a synonym, maybe encouraged by Symes description of "tassel-like" capillary underwater leaves (Syme 1863: 20). This concept was accepted by Casper & Krausch (1981), Wiegleb & Herr (1983) and many others, accentuating the high morphological variability of *R. penicillatus* in this circumscription. In the previous issue of the excursion flora of Austria (Englmaier 2008), *R. pseudofluitans* was thus included in a broader *R. penicillatus*. In contrast, Webster (1988) examined all the relevant material in Symes herbarium and did not find any specimen with laminate, swimming leaves and with numerous branches in their capillary underwater leaves corresponding with the type of *R. penicillatus* and with fig. 26 in Cook (1966: 157). However, she found specimens habitually similar to *R. fluitans* without any swimming leaves. She newly combined *R. pseudofluitans* as a separate subspecies under *R. penicillatus* and designated a lectotype from Symes material. As the clearest morphological gap was found between *R. fluitans*-like plants without any swimming leaves and *R. peltatus*-like ones occasionally sprouting laminate, swimming leaves and with shorter, densely branched underwater leaves, a concept of distinct species is applied here, the former placed in the *R. fluitans* group, the latter in the *R. aquatilis* group.

Description: *Ranunculus pseudofluitans* is a perennial herb, quite variable, habitually similar to *R. fluitans* but differentiated from *R. fluitans* mainly by slightly shorter leaves with regularly 3 subparallel floating segments and some floral characters: Petals may be smaller, sometimes even not overlapping and the receptacles are always (densely) pubescent. In contrast, nectaries are variable, semicircular to slightly pyriform and do not provide a suitable differentiation. Flowers have 10–40 stamens. Nutlets are similar to those of *R. fluitans*, 1.5–1.8(2.0) mm long, sometimes variably bristled along the keel.

Low fruit setting may be either caused by flooding of the flowers (as Freyn 1890 suggested for *R. fluitans*) or by its hybridogenous nature. Thus, *R. pseudofluitans* will frequently occur as clonal populations, resulting in high variability between different populations as well as high uniformity in single clones occurring over long river stretches, as Sonnberger (2012, 2013) impressively illustrated with different, so called "types" in his investigation area.

Ranunculus pseudofluitans is mainly tetraploid ($2n = 32$). Cook (1962) reported a single count on fertile material from Sigmaringen, Württemberg, Germany under "*R. pseudofluitans* complex", later (Cook 1966: 168) the same under *R. penicillatus* var. *calcareus*.

Habitat: Unlike *R. fluitans*, its ecological amplitude is much broader, thus mainly growing in river stretches with elevated mineral nutrient load or with elevated hydrogencarbonate buffering capacity where *R. fluitans* may be already suppressed.

Occurrence within the territory: N [†: bei Traismauer nächst Hollenburg a. d. Donau/ in einem Bache, 2. 7. 1922 leg. F. Vierhapper, WU 073978], **St** [Englmaier 2015], **S** [–: Englmaier 2015], **BAY** [Sonnberger 2012, 2013], **Lom** [†: Luganersee Ponte Tresa, verschlammte Buchten, first half of 20th century, leg. R[udolf] Sarnthein, IBF 075389], **TAA** ["Alte Etsch" bei Spondinig, No. 6462 and Lichtenberger Bach SE Lichtenberg, No. 6461, both 15. 8. 1982, Hb. B. Wallnöfer; Nel fosso tra il mulino e il Brenta 400 m a S della piscicoltura di Serafini (Valsugana, TN), 234 msm, 24. 4. 1996, leg. F. Prosser, ROV 26688].

***Ranunculus trichophyllus* group (*R. trichophyllus*, *R. confervoides*, *R. rionii*)**

Only *R. rionii* shows anatomically different aerial leaves, the other (homophyllous) species reduce the length of their leaf segments by withering the tips when falling dry. All European species have small flowers with small-ovoid, usually non-overlapping, deciduous petals, semicircular nectaries and are facultatively cleistogamous.

(3) *Ranunculus trichophyllus* (*Batrachium trichophyllum*, *R. divaricatus*, *R. flaccidus*, *R. paucistamineus*)
Misapplied names: *Batrachium carinatum*, *R. petiveri*, *R. pantothrix*

Description: *Ranunculus trichophyllus* is a perennial (rarely annual) herb, hibernating with rhizomes and short shoots in the water body near the substrate surface. During the vegetative season it grows up to numerous, 0.5–3 m long shoots with freely floating tips.

It is strictly homophyllous, has only underwater leaves with filamentous segments, from 20 up to 50 mm long, branched three-fold, at each branch divided into 4–5 segments (**Fig. 1.3**), all of them equal in length, spread out under (stagnant) water but immediately collapsing when taken out of the water. Leaves are usually shorter than internodes of fully elongated shoots. Stipules are long-ovoid, small, never exceeding 4 mm in length. Pedicels are as long as their bracts and up to as long as the previous internodes, not elongated, but often slightly recurved in fruit. Flowers are emergent (mainly allogamous and fully opened, even when occasionally flooded after pollination) or submergent, (usually in fast running waters, then not fully opened and thus cleistogamous), 8–12(15) mm in diameter. Sepals are more than ½ as long as petals, adherent to the petals. Petals are long-lanceolate, not overlapping, deciduous, their nectaries are semicircular. In most cases flowers have only few (10–15) stamens. Receptacles are hemispherical, pilose. Only few nutlets (15 up to 30) are on a receptacle, they are 1.5–1.7 mm long, keeled, frequently bristled along the keel, with 5–7 lateral ribs and the style remnant on the side (**Fig. 3.5**). Plants are always fully fruiting (due to cleistogamy).

Di- ($2n = 16$), tetra- ($2n = 32$) and hexaploids ($2n = 48$) are reported in literature, together with aneuploids, although the vast majority of individual counts indicate tetra-

ploids. Except for the Iberian peninsula (Diosdado & Pastor 1996: 169, from Sevilla), all diploid data in literature were found to be based on one single record, Langlet (1927), and Cook (1966: 170) notes on this "Origin and voucher unknown". Contrary, hexaploids were recorded from the Aegean area (Dahlgren & Cronberg 1996), together with tetraploids.

Aneuploid (triploid or pentaploid) intraspecific hybrids are possible and may result in well-growing, even flowering, but never fruiting populations, giving a hint on their origin. Sometimes they are widely distributed in river stretches by vegetative propagules (shoot tips). Pentaploids (Dahlgren 1991) may belong to an autopolyploid series of Aegean *R. trichophyllus* (not present in the territory), but may also result from hybridization between *R. trichophyllus* and *R. aquatilis* or *R. penicillatus.* Confusion with the sterile, well-growing triploid hybrid *R.* "×*glueckii*" (*R. trichophyllus* × *R. circinatus*) may occur, but *R.* "×*glueckii*" can be separated from other sterile *R. trichophyllus* hybrids, as it forms only small, atrophied buds, but no receptacles, and its leaves are not completely collapsing when taken out of the water.

The size of all parts, stems, leaves, flowers and even fruits seems to be slightly dependent on the individual ploidy level, but also (and strongly exceeding these effects) on habitat characteristics as duration of growth period, water depth, flow rate, nutrient content, pollution level as well as interspecific competition. Growth rate and shape of the plants may differ widely, fully contrasting with the apparent uniformity of plants in a single stand or river stretch. This fact may result in widespread misinterpretation and unclear synonymy. Impressive examples are "*R. petiveri*" and "*R. pantothrix*". Confusion with other species, mainly *R. penicillatus* s. str., may also occur.

Habitat: *Ranunculus trichophyllus* is mainly found in running, but also in stagnant, clear, buffered waters (in limestone bedrock areas), on pebbly to silty substrates, 0.1–3 m in depth, from mountains to lowlands. It is slightly tolerant to elevated mineral nutrient contents even in weakly buffered waters and thus (besides *R. peltatus*, *R. penicillatus* s. str. or *R. pseudofluitans*) occasionally occurring in silicaceous (mainly mafic) bedrock areas.

Occurrence within the territory: B, W, N, O, St, K, S, Nord**T, V** [**!**: Jäger 2013], **BAY**, **Lom** [Martini & al. 2012], **TAA**, **Fri** [Poldini 1991].

(4) *Ranunculus confervoides* (*Batrachium eradicatum*, *R. aquatilis* var. *eradicatus*, *R. trichophyllus* subsp. *eradicatus*, *R. lutulentus*, *R. trichophyllus* subsp. *lutulentus*)

Description: *Ranunculus confervoides* is mainly a tenuous, annual herb, hibernating as nutlets. During the vegetation period it grows up to some weakly rooting or freely floating, up to 0.5–1 m long, thin shoots (never more than 1 mm in diameter) with roots on every node.

It is strictly homophyllous, has only underwater leaves with filamentous segments, rarely exceeding 20 mm in length, branched two- or three-fold, at each branch divided into 3–4 segments, all of them equal in length, spread out under (stagnant) water but immediately collapsing when taken out of the water. Leaves are generally shorter than internodes of fully elongated shoots. Stipules are long-ovoid to triangulate, small, up to 2–3 mm in length.

Pedicels are longer than their bracts but not longer than the previous internodes. Flowers are submergent or emergent, cleistogamous, 6–8 mm in diameter. Sepals are slightly shorter than petals, adherent to the petals. Petals are long-lanceolate, not overlapping, deciduous, with semicircular nectaries. Flowers have 8–12 stamens. Receptacles are hemispherical, pilose. Only few (10–18) nutlets are on a receptacle, they are 1.5–1.7 mm long, keeled, glabrous or weakly bristled along the keel, with 7–9 lateral ribs and the style remnant slightly at the side. Usually, plants are fully fruiting.

Ranunculus confervoides is relatively constant in its characters, shooting is mainly dependent on water depth: deepwater forms are often distinctly elongated, shoots in shallow water are more densely foliated. In most cases, roots are developed on all nodes.

Ranunculus confervoides is tetraploid ($2n = 32$). Cook (1966: 171–172) cites several counts on arctic and alpine material.

Habitat: Within the territory, *R. confervoides* is mainly found in high alpine lakes, mainly above (1800)2000–2500 msm, from 0.1 to several meters deep, in clear, well-buffered carbonate waters. Some records in low altitude listed in Drozdowski & al. 2015 need a critical re-examination to avoid confusion with small-grown *R. trichophyllus.*

Occurrence within the territory: O, **St**, **K** [**e**], **S**, Ost**T**, Nord**T** [**e**], **V** [**!**: Jäger 2013; Hochalpsee, Allgäuer Alpen, 1998, leg. Dörr, IBF 1537], **BAY** [Geißalp[en]see, Rappensee (Gutermann 1960: 28), Funtensee (Cook 1966: 139)], **FL** [**e**], **GR** [**e**], **Lom** [Martini & al. 2012], **TAA**, **Fri** [**e**].

(5) *Ranunculus rionii* (*Batrachium rionii*, *B. trichophyllus* subsp. *rionii*, *Ranunculus trichophyllus* var. *rionii*, *R. trichophyllus* subsp. *rionii*)

Description: *Ranunculus rionii* is an annual herb, hibernating as nutlets. In its freewater form it can grow up to 0.5–1 m long shoots, but it is frequently found as a terrestrial modificant with up to 0.2 m long, creeping and branched stems.

It is heterophyllous with two leaf types, collapsing underwater and rigid terrestrial leaves, the former 20–25 mm long, usually shorter than internodes of fully elongated shoots, branched three-fold, at each branch divided mainly into 4 segments of equal length. Terrestrial leaves are much shorter, 10–15(20) mm long, branched 2–3 fold in two or three segments. Stipules are long-ovoid, up to 4 mm in length, but much shorter with terrestrial leaves.

In its freewater form, pedicels are usually longer than their bracts and as long as or slightly longer than the previous internodes. Flowers are submergent or emergent, 6–12 mm in diameter. Sepals are slightly shorter than petals, adherent to the petals. Petals are long-lanceolate, not overlapping, deciduous, with semicircular nectaries. Flowers have (10)12–25 stamens. Receptacles are at least long-ovoid to cylindrical, pilose. Dependent on the size of the plant, on each receptacle only few (dwarf specimens with only one flower may have less than 20 nutlets) or numerous, up to 60(100) small (1–1.4 mm long), keeled nutlets are found. They are glabrous or weakly bristled along the keel, with 6–8 lateral ribs and the style remnant slightly on the side. Plants are fully fruiting.

Ranunculus rionii is diploid ($2n = 16$), reported from Austria and Iraq by Cook (1966: 172). Freewater plants are relatively uniform in length and size, but the size of terrestrial modificants mainly depends on their water supply.

Habitats: *Ranunculus rionii* is found in ephemeral aquatic habitats such as wheel ruts, puddles or any small pools and may outlive dry periods as nutlets, up to a decade. It is distributed in all regions, but mainly overseen or confused with *R. trichophyllus* and thus inadequately represented in distribution maps.

Occurrence within the territory: B, **W**, **N** [Cook & Patzak 1962], Nord**T** [**f**: Polatschek 2000: no corresponding specimen was found in W], **TAA** [**!**: Laghetti di Marco, Rovereto, 29. 5. 1991 leg. Prosser & Festi, ROV 9952; Taio di Nomi, 20. 7. 1986 leg. Festi, ROV 9953], **Fri** [**e**].

Ranunculus aquatilis group

When fully developed, all the species have a leaf succession from weak, capillaceous underwater leaves to laminate swimming leaves and to rigid, capillaceous terrestrial leaves. Cook (1969) presented some results on the photoperiod-triggered initiation of heterophyllous growth.

Unfortunately, a lot of specimens are collected with underwater leaves only, complicating determination and resulting in some confusion of species within the group or even with *R. trichophyllus*. But also fully developed plants with laminate, swimming leaves are confused, as the different details in leaf silhouettes are neglected (Holzner & al. 2015: 205, fig. 1b is *R. peltatus*, not *R. aquatilis*, and Hohla 2011: 155, fig. 18 is *R. aquatilis*, not *R. peltatus*). Usually, all the species have large flowers with broad-lanceolate, overlapping petals, and nectaries of various shape. All of them are regularly allogamous.

The *Ranunculus aquatilis* group consists of two similar and highly confusable subgroups:

(1) the ***Ranunculus aquatilis* subgroup**, present in the territory with one single species, *R. aquatilis*.

It has rounded, 3–5 fold deeply dissected laminate leaves with acuminate segments. Its characteristic transition leaves ("mosaic leaves") have both capillary and laminate sections (Cook 1969: 474, fig. 4).

(2) the ***Ranunculus peltatus* subgroup**, present in the territory with two species, *R. peltatus*, and *R. baudotii*. Their laminate leaves are approximately semicircular, three-lobed, mainly with rounded segments. Transition leaves found in *R. peltatus* and *R. baudotii* show a laminate basis and a capillary apex and will appear, if plants are flooded just when beginning to form laminate leaves (Englmaier 2014b: 328, fig. 34).

Although the phylogeny of *Ranunculus* by Emadzade & al. (2011) is of poor resolution in detail, they suggest a gap between these subgroups, whilst *R. peltatus* seems to be closely related to *R. trichophyllus*, *R. aquatilis* is genetically most isolated (Hörandl & Emadzade 2012: 317, fig. 2).

Surprisingly, Emadzade & al. (2011) placed *R. penicillatus* nearby to *R. aquatilis*, but this fact is supported by a single sample coming from England and determined as "ssp. *pseudofluitans*"). By contrast, Zalewska-Gałosz & al. (2014) present "*R. penicillatus*"-populations from southwestern Poland as originating from *R. fluitans* and *R. peltatus*. Bobrov & al. (2015) treat their newly described *R. schmalhausenii* from Fennoscandia of hybridogenous origin, being also related to *R. peltatus*. Consequently, none of these hybridogenous taxa is placed in any certain subgroup here.

Ranunculus aquatilis subgroup

(6) *Ranunculus aquatilis* (*Batrachium aquatile*, *Rancunulus heterophyllus*, *R. radians*)
Misapplied name: *Batrachium carinatum*

Description: *Ranunculus aquatilis* is an annual or perennial herb, facultatively hibernating with rhizomes and short shoots near the substrate surface of deep waters. During the vegetation period it grows up to 0.5–2 m long shoots with freely floating tips.

It is regularly heterophyllous when flowering, except in remarkably deep stagnant waters. It can even germinate in different modificants as depicted by Arber (1920: 196). Underwater leaves are filamentous, from 20 up to 50 mm long, branched three-fold, at each branch divided into 4(5) segments, all of them equal in length, spread out under (stagnant) water but immediately collapsing when taken out of the water. Underwater leaves are usually shorter than internodes of fully elongated shoots. Stipules are broadly ovoid to triangulate, usually slightly more than 5 mm in length. Its swimming leaves are nearly circular, deeply dissected, with multiple secondary lobes (**Fig. 2.1**). Transition leaves are often present. They are of mosaic leaf type and usually show lobes like an underwater leaf as well as others with their typical lamina shape in one leaf (**Fig. 2.2**).

Flowers may grow up in the axils of each leaf type. If the bract is an underwater leaf type, pedicels are as long as their bracts and not longer than the previous internodes, but if the bract is a swimming leaf type, pedicels are slightly shorter than the petioles and will be slightly longer when fruiting.

Flowers are emergent, 15–20 mm in diameter. Sepals are ½ as long as petals, adherent to the petals. Petals are broad-lanceolate to ovoid, overlapping, persistent during the flowering period, with circular nectaries. Flowers have 15–25 stamens. Receptacles are hemispherical, pilose, with 30–40 nutlets. These are 1.4–1.7 mm long, keeled, bristled along the keel, but frequently becoming glabrous when ripening, with some – faintly visible – lateral ribs and a style remnant on the keel side (**Fig. 3.1**).

Ranunculus aquatilis is hexaploid (2*n* = 48). Cook (1966: 169–170) gave numerous examples.

Habitat: *R. aquatilis* needs moderately shallow stagnant or very slowly running waters, mainly with a rapidly warming water surface such as ditches or small ponds in a rural surrounding. The warming of the water surface, together with an elongated photoperiod (Cook 1969) seems to induce swimming leaf formation. It is slightly tolerant to elevated mineral nutrient contents. Once profiting from traditional agricultural land use with a lot of communal ponds ("geese ponds"), it lost nearly all its preferred microhabitats in present days. It is mainly distributed by domestic water fowl, either as shoot tips or as nutlets.

Occurrence within the territory: B [†], **W** [†], **N** [†], **O** [Hohla 2011: 155, fig. 17, 18, named as *R. peltatus*], **St** [†], **K** [†], **S** [†], Nord**T** [†: Lans [S of Innsbruck], Gräben, hfg. 19th century, leg. Murr, IBF 146996; In einem Tümpel zwischen Vill und der Poltenhütte [S of Innsbruck], 6. 1911, leg. Beer, IBF 116354; bei Igls, 8. 1897 leg. [M.] Hellweger, IBF 115484; Innsbruck: In einem langsam fließenden Bächlein am Wege nach Lans kurz vor der Öllachervilla (loc. class.) nicht jedes Jahr! 5. 1898, leg. M. Hellweger, IBF 123386], **Lom** [†], **TAA** [†], **Fri** [**?**].

Ranunculus peltatus subgroup (*R. peltatus*, *R. baudotii*)

(7) *Ranunculus peltatus* (*R. aquatilis* subsp. *peltatus*, *R. triphyllos*, *R. floribundus*, *R. rhipiphyllus*, *Batrachium langei*)
Misapplied name: *R. petiveri*

Description: *Ranunculus peltatus* is usually a perennial herb, hibernating with rhizomes. During the vegetation period it grows up to 0.5–3 m long shoots with freely floating tips.

It is regularly heterophyllous, except in deep stillwaters or near the ground of fast running creeks. Its underwater leaves are filamentous, from 20 up to 50 mm long,

branched three-fold, at each branch divided into 4(–5) segments, all of them equal in length, spread out under (stagnant) water but fully collapsing when taken out of the water. Underwater leaves are usually shorter than internodes of fully elongated shoots. Stipules are broadly ovoid to triangulate, slightly more than 5 mm in length. Its swimming leaves are semicircular, deeply three-lobed, frequently with only one secondary lobe (**Fig. 2.3**). Transition leaves may be present in case of water level fluctuations as flooded immature swimming leaves may continue growing with filamentous tips (**Fig. 2.4**).

When germinating on wet substrate it will regularly form only terrestrial leaves, rarely a pair of laminate leaves first.

Flowers may grow up in the axils of each leaf type. If the bract is an underwater leaf type, pedicels are as long as their bract and not longer than the previous internodes, but if the bract is a swimming leaf type, pedicels are slightly longer as the petioles, sometimes become slightly recurved and somewhat elongated when fruiting.

Flowers are emergent, (15)18–25(30) mm in diameter, thus among the largest flowers within the sect. *Batrachium*. Sepals are less than ½ as long as petals. Petals are broad-lanceolate to ovoid, (sometimes slightly) overlapping, persistent during the flowering period, with (deeply) pyriform nectaries. Flowers have 15–25(30) stamens. Receptacles are hemispherical, pilose, with 30–40 nutlets. These are 1.8–2(2.2) mm long, keeled, bristled along the keel, but frequently becoming glabrous when ripening, with 8–12 tenuous lateral ribs and a very small style remnant at the side (**Fig. 3.2**).

Di- ($2n = 16$), tetra- ($2n = 32$) and hexaploids ($2n = 48$) were found (Cook 1966: 167–168), diploids in the Iberian peninsula (as in *R. trichophyllus*!), hexaploids only in GB/Hampshire, and a confusion with *R. penicillatus* cannot be ruled out. The size of all parts is nearly independent of the individual ploidy level. Tall grown specimens may be confused with *R. penicillatus* s. str. (and vice versa).

Habitat: *R. peltatus* grows in running waters, even in creeks, as well as in stillwaters, from the shoreline (frequently in a terrestrial modificant) to few meters deep water bodies. It strictly needs unbuffered water and thus never occurs in limestone areas. It will also disappear when exposed to just slightly elevated mineral nutrient contents.

Present in areas with silicaceous bedrock or lime-free sediments, even in ponds on red clay soils in karst areas.

Occurrence within the territory: N, **O**, **St** [†: Aich im Ennsthal: Am Weg nach Weissenbach, in und an dem am Weg vorüberfliessenden Bach, häufig; ca. 700 m. 21. 8. 1898 leg. Palla W 1954/262], **K**, **S** [–: Tennengau, St. Jakob am Thurn, Schlickflächen im z. Z. fast ausgetrockneten See (terrestrial modificant), 515 msm, 25. 9. 1992, leg. P. Pilsl, Hb. Pilsl No. 9230], **TAA** [†: In Pfützen bei Natz nächst Brixen, Mai, 19th century, leg. Schmuck, SZB 23337; stagno del Lavazzè (Fiemme), 29. 7. 1895 leg. E. Gelmi, WU 074117].

(8) *Ranunculus baudotii* (*Batrachium baudoti*, *R. aquatilis* subsp. *baudotii*, *R. peltatus* subsp. *baudotii*, *R. confusus*, *Batrachium carinatum*, *B. marinum*)
Misapplied names: *R. petiveri*, *R. peltatus* subsp. *fucoides*, *R. peltatus* subsp. *saniculifolius*

Description: *Ranunculus baudotii* is mainly annual and hibernates with nutlets in the sediment. Its characteristic growth form with elongated fruit peduncles enables the plant to place the nutlets directly in the (silty) water bottom sediment.

Dependent on its particular habitats it either grows as a small herb with stems less than one meter in small ponds or as a freely floating bundle of shoots up to 3 m or more in large and deep water bodies such as coastal lagoons. It can even grow as a terrestrial modificant along the shoreline.

It frequently remains homophyllous, even in its large growth form ("*Batrachium marinum*"), but sometimes forms swimming leaves, mainly in shallow waters. Its underwater leaves are filamentous, from 20 up to 50 mm long, branched three-fold, at each branch divided into 4–5 segments, all of them equal in length, spread out under (stagnant) water and slightly collapsing when taken out of the water. Underwater leaves are usually shorter than internodes of fully elongated shoots. Stipules are broadly ovoid to triangulate, usually about 5 mm in length with vigorous specimens. Its swimming leaves are like those of *R. peltatus*, sometimes with very deep sinuses (**Fig. 2.5**). Usually typical transition leaves are not present.

Flowers may grow up in axils of all leaf types. If the bract is an underwater leaf type, pedicels are as long as their bract and not longer than the previous internodes, but if the bract is a swimming leaf type, pedicels are as long as the petioles, but will become elongated up to 3–4 fold and recurved when fruiting

Flowers are emergent, (12)15–18 (20)mm in diameter, the terrestrial form usually bearing extremely small flowers. Sepals are much shorter than petals (less than ½ as long as petals), slightly deflexed. Petals are broad-lanceolate to ovoid, (sometimes slightly) overlapping, persistent during the flowering period. Both sepals and petals may have a bluish cast, sepals are bluish shaded, petals may have bluish tips. Nectaries are semilunar, but may be variable. Flowers have 10–20(25) stamens.

Receptacles are ovoid to cylindrical, pilose, with 30–60 nutlets. These are remarkably small, only 1–1.4 mm long, keeled, glabrous, alate at the keel, with 8–12 tenuous lateral ribs and an elongated style remnant on the keel side (**Fig. 3.6**).

Ranunculus baudotii is tetraploid ($2n = 32$). Cook (1966: 167) reports chromosome numbers from coastal and inland habitats.

Variable in size and foliage, thus sometimes split up in two distinct species (*R. baudotii* s. str. and *R. marinus*). Luther (1947: 24) states the latter as a tall-growing, homophyllous habitat modification of shoreline lagoons only, but it can be observed, that it is also found in inland waters along bird migration routes coming from the Baltic Sea.

Habitat: *R. baudotii* will mainly grow in stagnant waters with elevated mineral load or salinity, in coastal areas as well as in inland mineralized springs, even in karstic waters (Spałek & Proćków 2011) and waters with elevated intake of mineral fertilizers.

Occurrence within the territory: B, **W** [†: Wien, Prater, 1909 leg. Beer, IBF 083415; Wiener Neustädter Kanal, Wien, Zentralfriedhof. Locus classicus, 1909, leg. I. Dörfler, named as *R. carinatus*, IBF 123387], **N**, Nord**T** [**f**: Wipptal, Brennersee nahe N Brenner, 1340 msm. Wasserbereich und weiterer ruderaler Uferbereich, 21. 9. 1991 leg. A. Polatschek, named as *R. baudotii*, W 1992-17268 is *R. trichophyllus*], **TAA** [**f**: "Reschen See", September, first half of 20th century, leg. R[udolf] Sarnthein, named as *R. baudotii*, IBF 021860].

(9) *Ranunculus penicillatus* s. str. (*Batrachium penicillatum*, *R. aquatilis* subsp. *penicillatus*, *R. penicillatus* var. *vertumnus*; excl. *R. pseudofluitans*)

Several hybridogenous complexes exist within the section *Batrachium*. Within the territory, two of these complexes are well established and treated as species here: Besides the *R. fluitans*-like *R. pseudofluitans* (see *R. fluitans* group), *R. penicillatus* s. str. is the other one, with participation of several species of the *R. aquatilis* group, but not restricted to an origin from *R. aquatilis* × *R. peltatus* only, and definitely not a hybrid *R. peltatus* × *fluitans*, as Holzner & al. (2015: 206) argued. It is quite heterogenous in morphological and ecological characteristics and thus, if studied on insufficient material, confusable with any of the species within the *R. aquatilis* group.

Description: *Ranunculus penicillatus* is usually a perennial herb, hibernating with rhizomes. During the vegetation period it grows up to 1–4 m long shoots with freely floating tips.

In many cases it remains homophyllous. Its underwater leaves are filamentous, from 30 to 60 mm long, branched three-fold, at each branch divided into (4)5 or more segments, especially of 3rd order (looking paintbrush-like, **Fig. 1.4**), all of them equal in length, spread out under (stagnant) water but (partially) collapsing when taken out of the water. Underwater leaves are usually slightly shorter than the internodes of fully elongated shoots. If present, its swimming leaves are semicircular, deeply three-lobed, quite similar to those of *R. peltatus*, usually with smaller sections. Irregularly shaped transition leaves may be found as an exception. Stipules are variable, broadly ovoid to triangulate, usually about 5 mm in length.

Pedicels are as long as their bracts and not longer than the previous internodes, not thickened at the base, usually not recurved, not markedly elongated when fruiting. Flowers are emergent, highly variable in its dimensions (15–25 mm in diameter, generally smaller dimensioned in populations within the territory). Sepals are less than ½ as long as petals, adherent to the petals. Petals are of various shape, sometimes overlapping,

persistent during the flowering period, with variably shaped, circular to (slightly) pyriform nectaries. Flowers have 20–40 stamens, usually more than the other *Batrachium* species.

Receptacles are hemispherical to slightly ovoid, pilose, with 30–40(50) nutlets. Nutlets are 1.8–2 mm long, keeled, bristled along the keel, but frequently becoming glabrous when ripening, with 8–10 tenuous lateral ribs and a conspicuous style remnant on the keel side (**Fig. 3.3**).

Ranunculus penicillatus s. str. was frequently confused with *R. pseudofluitans* and *R. peltatus*. One may succeed in separation of *R. penicillatus* s. str. from *R. pseudofluitans* when considering underwater leaf shape, branching and length compared with its preceding stem internode, and from *R. peltatus* when considering underwater leaf branching together with laminate leaf abundance and shape.

Ranunculus penicillatus is mainly hexaploid (2*n* = 48), Cook (1966: 168) gives an example from Ireland and Cook (1962: 125) reports three counts from England and one from Upper Bavaria under "the *pseudofluitans* complex", Cook (1966: 168) differentiated these into "var. *vertumnus*" from Greywell, and "var. *calcareus*" from the other localities, but all seem to refer to *R. penicillatus* in the circumscription presented here.

Habitats: *Ranunculus penicillatus* s. str. grows in various habitats, mainly in lowlands, even in buffered waters and those with slightly elevated mineral nutrient contents.

Occurrence within the territory: N [†: Im Kalten Gang oberhalb Velm, Niederösterreich, 29. 8. 1921 leg. H. Zerny, named as *R. paucistamineus*, W 1958-14629; In der Fischa bei Marienthal nächst Gramatneusiedl, 8. 7. 1905 leg. J. Vetter, named as *R. paucistamineus*, rev. C. D. K. Cook, W 1947-15238; Wassergr[aben] Moosbrunn [south of Vienna], 8. 7. 1905 Hb. E. Janchen, named as *R. fluitans*, W 1968-11833], **O** [Hohla 2001: 327; Im Moosbach bei Oberminathal, Gemeinde Maria Schmolln, 520 msm, 21. 5. 1985 leg. R. Krisai; In der Mattig in Aiching, Gemeinde Braunau a. Inn, 12. 6. 1974, leg. R. Krisai, both named as *R. fluitans*, private Hb. Krisai], **St** [**?**: Maurer (1996: 92): "Für St. nicht mit Sicherheit nachgewiesen"], **K** [**!**: Englmaier 2016], **Lom** [**!**: Valtellino: Ardenno, 270 msm, 18. 7. 2016, P. Englmaier, unpublished; Martini & al. (2012: 460), possibly including *R. pseudofluitans*, needs a verification], **TAA** [**!**: Nel Sarca a Villa Rendena (Val Rendena, TN), 570 msm, 2. 6. 1994, leg. F. Prosser, ROV 17451; Lungo il Noce al ponte di Croviana (Val di Sole, TN), 705 msm, 22. 5. 1996, leg. F. Prosser, ROV 27100], **Fri** [e], **SLO** [e].

(10) *Ranunculus circinatus* (*Batrachium circinatum*, *R. stagnatilis*)
Misapplied names: *R. fucoides*, *R. divaricatus*, *R. stagnalis*

Description: *Ranunculus circinatus* is an annual or (mainly) perennial herb. It is strictly homophyllous, all leaves resemble the anatomy of a terrestrial modificant with some

stomata, thus underwater leaves appear as rigid and non-collapsing (line drawing by Hegi 1912 in Englmaier 2014b: 321, fig. 13, left). Dependent on its habitat, it can grow up to 0.5–2.5 m long, floating shoots or can grow as short creeping stems in very shallow waters or (ephemerally) on wet sediment surfaces.

Its leaves are filamentous, from (10)15 up to 20(25) mm long, much shorter than internodes of fully elongated shoots, branched three-fold, at each branch divided into 4–5 segments, all of them equal in length, spreading when taken out of the water (**Fig. 1.2**). Does not develop different terrestrial modificants, but can survive terrestrially over short periods. Stipules are long-elliptical, usually about 5 mm in length.

Pedicels are as long as the internodes and become only slightly longer, but usually recurved when fruiting.

Flowers are emergent, 15–20 mm in diameter. Contrary to other species with terrestrial modificants, terrestrial growing plants will never blossom. Sepals are half as long as petals. Petals are broadly lanceolate to ovoid, (sometimes slightly) overlapping, persistent during the flowering period, with deeply semicircular nectaries. Flowers have 20–25 stamens. Receptacles are slightly ovoid, pilose, with 40–50 nutlets. These are 1.4–1.7 mm long, keeled, sparsely bristled along the keel, with 6–10 tenuous lateral ribs and the style remnant at the side.

Ranunculus circinatus is diploid ($2n = 16$). Cook (1966: 173) gives numerous records throughout Europe.

Habitats: *Ranunculus circinatus* mainly grows in eutrophic stillwaters in lowland areas, such as lakes or oxbows.

Occurrence within the territory: B, **W**, **N**, **O**, **St**, **K**, **S**, Nord**T**, **V** [**!**: Jäger 2013: 117], **Lom** [Martini & al. 2012], **TAA**, **Fri** [**e**], **SLO** [**e**].

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