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First evidence of a heterophyllous water crowfoot (*Ranunculus peltatus*, Ranunculaceae) in Iran, its phytogeographical implications and a new determination key for Iranian *Batrachium*

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Abstract

Ranunculus peltatus (*Ranunculus* subgen. *Batrachium*, *Ranunculaceae*) is documented from aquatic wetlands of NW Iran. It is the first evidence of heterophyllous *Ranunculus/Batrachium* populations for Iran. The two newly found populations were identified as *Ranunculus peltatus*, known from a wide range of habitats in unbuffered, running or stagnant water throughout Europe. The *Ranunculus peltatus* group is a polymorphic group of confusable taxa, usually placed on species or subspecies rank. The distinguishing features of the known Iranian members of *Ranunculus* subgen. *Batrachium* are presented in a determination key and the role of migrating waterfowls in the dissemination of aquatic plants over long distances is discussed.

Key words: Flora of Iran, new record, *Ranunculus peltatus*, distribution pathway, waterfowl migration, wetlands.

Introduction

Nearly 60 taxa of the genus *Ranunculus* L. (*Ranunculaceae*) have been recorded from Iran, few of them treated as a separate entirely aquatic genus *Batrachium* (DC.) S.F. Gray (Iranshahr & al. 1992).

During the times the status of *Batrachium* has varied from a section to a genus (Rossmann 1854, Cook 1963, Dahlgren 1992, Pizarro 1995). It cannot be confused with any other genera of the *Ranunculaceae*. However, it can only be separated from *Ranunculus* by the combination of two characters (transversely-ridged fruits and lusterless petals, Parkin 1928, Cook 1963, 1966). According to Cook (1963, 1966) the level of differentiation is insufficient to merit a generic status and the rank as a distinct subgenus within the large genus *Ranunculus* was confirmed in recent molecular phylogenetic studies (e.g. Emadzade & al. 2010). Following this arguments *Batrachium* is treated here on subgenus rank within *Ranunculus*.

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Ranunculus subgen. *Batrachium* can be divided in several groups of similar and highly confusable taxa (first attempts in Kreczetowicz 1937, recent version by Englmaier 2008, 2014). Among them, two groups of species are heterophyllous with occasionally developed floating leaves: the *R. aquatilis* group and the *R. peltatus* group.

Ranunculus subgen. *Batrachium* mainly shows a western Eurasian distribution, with the exception of some species of the *R. aquatilis* and the *R. trichophyllus* groups (Hoffmann & al. 2010). Thus, several species were already reported from Iran, namely *R. sphaerospermus* Boiss. & Blanche, *R. trichophyllus* Chaix ex Vill. and *R. rionii* Lagger (Iranshahr 1992). All these species have only submerse, capillary leaves and grow in various running and stagnant waters and wetland habitats.

Various other records of subgen. *Batrachium* species from Iran and its vicinity (Boissier 1867, Meikle 1959, Davis & Cook 1965, Parsa 1986, Riedl & Nasir 1990, Iranshahr 1992, Cook 1993, Hadač & Chrtek 2002) gave no further information.

Meikle (1959) states, that "plants with floating leaves are remarkably rare in the Orient". This statement may be relevant not only for homophyllous species itself, but also for heterophyllous species. In an early stage of development or mixed with certain homophyllous populations, they may have been overseen or misinterpreted, for example as *R. sphaerospermus* or *R. trichophyllus*.

Records of species of the *Ranunculus peltatus* group next to Iran came from the Mediterranean coast (*R. saniculifolius* Viv., Cook 1966), from Turkey (*R. kastamonuensis* Dönmez 2003), from the Black Sea (*R. baudotii* Godr., Danube delta, 2005, coll. Janauer, det. Englmaier), from the Caucasus region (*R. peltatus* as "*R. triphyllos* Wallr.", Kreczetowicz 1937), from Palestine (*R. baudotii*, Boissier 1867, but poorly reliable; *R. peltatus*, Meikle 1959), from Syria (Handel-Mazzetti 1913, two sheets of terrestrial modifications collected at Iskenderun, No. 52, WU 073983 and Adschule, No. 340, WU 073982, each labelled as "*R. aquatilis*", but both belong to the *R. peltatus*-group; *R. peltatus*, from Homs, Meikle 1959), and from Afghanistan ("*B. aquatile*", Tilli in valle Munjan, Iranshahr 1992, tab. 190, but the photograph of the cited sheet (Frey 420) shows a species belonging to the *R. peltatus* group, not *R. aquatilis*).

Citations of R. *aquatilis* L. var. *microcarpus* Meikle (Meikle 1959) from Syria (Antilebanon, leg. Hooker & Hanbury 1860; Zahlah, leg. Post 1875), Iraq (Khermal, leg. Rawi 1947), Afghanistan (Kabul, leg. Collett 1880; ibidem, leg. Hay 1935; Charasia, leg. Hay 1935; Begrami (= Bagrami), leg. Hay 1935) without floating leaves are not clearly identifiable to belong to the *R. peltatus* species group.

Material and methods

During field trips to Talesh Mts. (first author) and Bozqush Mts. (second author), plants of *Ranunculus* subgen. *Batrachium* with both submersed (underwater) and emerged (floating) leaves have been collected from aquatic wetlands. The specimens have been checked with various *Ranunculaceae* records from Iran given in the relevant literature (e.g. Boissier 1867, Kreczetowicz 1937, Davis & Cook 1965, Parsa 1986, Riedl & Nasir 1990, Iranshahr & al. 1992, Cook 1993). All materials of the herbaria W*, WU,

* Acronyms of herbaria follow Thiers 2015.

P and JE were critically examined. The material recorded here was deposited in the herbaria of the Mazandaran University, W and WU.

Results

Discovery of a heterophyllous water crowfoot

The plants were collected in stagnant waters more than one meter deep (Fig. 1). The species was accompanied by other wetland species such as *Alisma plantago-aquatica* L., *Butomus umbellatus* L., *Eleocharis palustris* (L.) ROEM. & SCHULT., *Hippuris vulgaris* L., *Lemna trisulca* L., *Polygonum amphibium* L., *Potamogeton crispus* L., *P. nodosus* POIR., *Schoenoplectus lacustris* (L.) PALLAS, *Sparganium erectum* L. and *Sparganium emersum* REHMANN.

A first determination using the keys in MAIRE (1964), COOK (1966), CASPER & KRAUSCH (1981), PIZARRO (1995), and the newly designed key in the Flora Istriaca (ENGLMAIER 2014) led to the *R. peltatus* species group (according to the floating leaf shape).

An additional search for related material in the herbaria W and WU gave one further result: A sheet, collected by Rechinger (W-Persia, Bakhtiari, Borujen, in fossis, 2. 6. 1974, Rechinger 47048 [WU 074916], det. as *"Batrachium trichophyllum"* by Iranshahr) shows a terrestrial modification with only the typical terrestrial leaf shape and some flowers with ovate-lanceolate, persistent petals. This material certainly belongs to *R. peltatus* and is the earliest evidence of a species from the *R. peltatus* group in Iran. Citations of *R. aquatilis* L. var. *microcarpus* MEIKLE (MEIKLE 1959) from Iran [Tak. (= Tagh) Bostan, leg. Cowan & Darlington 1929; "Terhrnar (?), Luristan" (correctly read as "Tschinar", meaning "Chenar", prov. Lorestan, near Khorramabad), leg. Haussknecht 1868; Asterabad, Bender Ges. (= Bandar-Gaz), leg. Sintenis 1901; Lar Valley NE Tehran, 7000 ft., leg. Trott 1943] with only underwater leaves are doubtful and might refer either to *R. peltatus,* to *R. baudotii* or even to *R. trichophyllus*. Nevertheless, not any heterophyllous *Batrachium* specimen was previously found in Iran.

Discussion

Morphological characteristics and identity of *Ranunculus peltatus*

The *Ranuunclus peltatus* group (see nomenclatural remarks) is morphologically close to the *R. aquatilis* group. However, the latter species have more complex, laminate floating leaves and in most cases typical transition leaves between the floating and the underwater leaf type (either one half of the entire leaf as floating type and the other tending to the underwater type or the shape of the complete lamina is intermediate). The species of the *R. peltatus* group usually show less complex leaves (mostly tripartite, the single sections are usually bifid) and rarely, even in rapidly running waters, "transition leaves", which are more deeply divided, with narrow tips. The *R. peltatus* group is very variable in size and shape, for the first glance the main species (*R. saniculifolius, R. baudotii, R. peltatus* s.str., also treated as subspecies by several authors) differ in their leaf shape

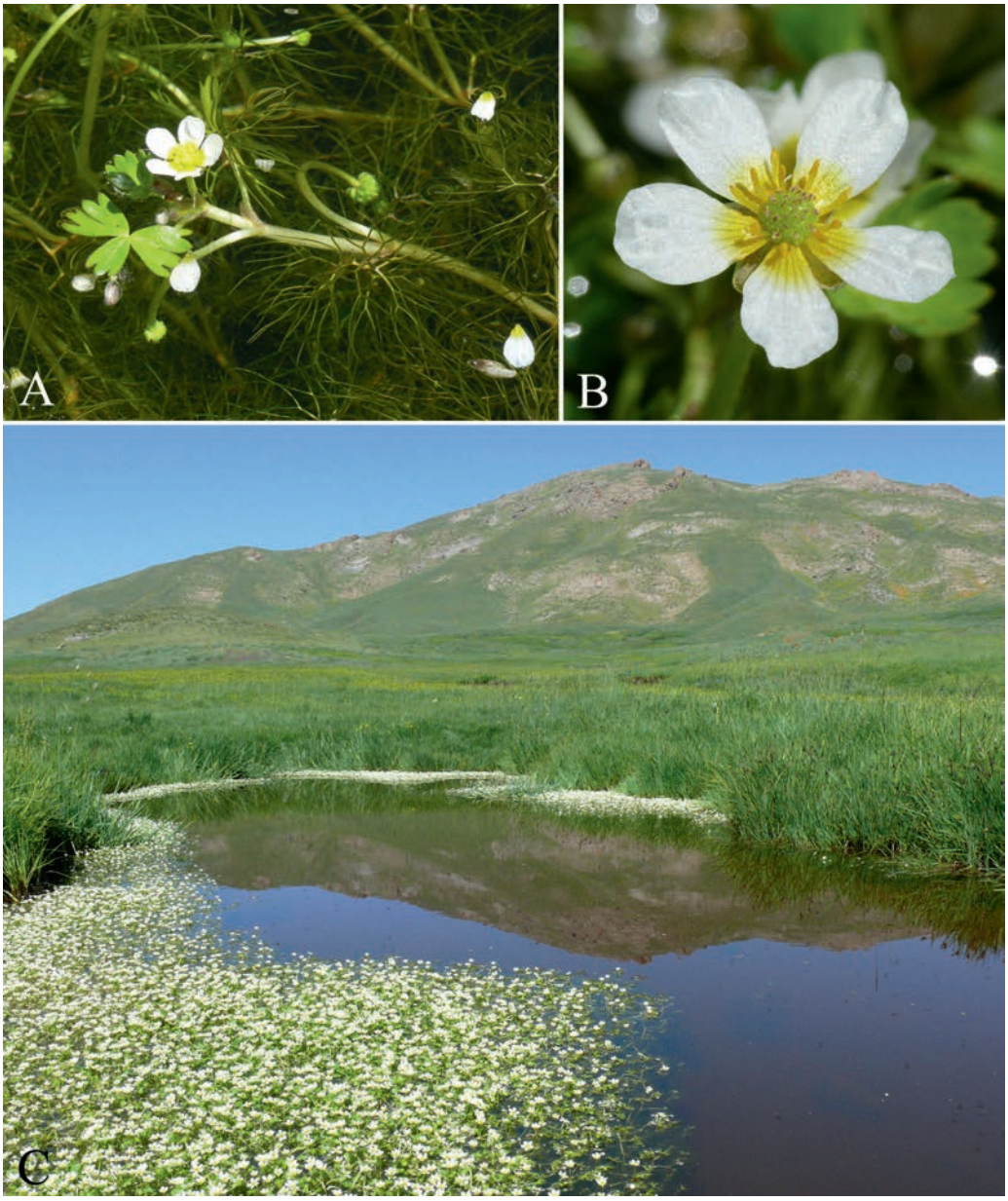

Fig. 1: *Ranunculus peltatus* in Bozqush mountains, NW Iran. A. flowering and fruiting stem with laminated (floating) and laciniated (submersed) leaves. B. flower, C. habitat of species – photos © J. Noroozi.

set: *R. peltatus* frequently shows floating leaves when flowering, *R. saniculifolius* has flowers only in the axils of floating leaves and sometimes terrestrial modifications bearing floating-type leaves, and *R. baudotii* will frequently occur without any floating

leaves, even when flowering. The high morphological plasticity of all these species is impressively shown, for example by MEIKLE (1959) for seed dimensions, COOK (1968) for stem and leaf morphology, flower and fruit dimension and nectary shape, WIEGLEB & HERR (1983) for stem and leaf morphology, leaf type succession and flower dimension, DAHLGREN & SVENSSON (1994) for leaf variability and GARBEY & al. (2004) for stem and leaf morphology.

Firstly the relatively small achenes (1.2–1.6 mm long) suggest an identification of this new Iranian material as *R. baudotii*. Such detailed characteristics as fruit shape and diameter, shape of the fruit receptacle, bluish tips of sepals and shape of nectary (refer to LEINFELLNER 1959) are very variable and one cannot see all of them perfectly in one single specimen. Some characteristics of Iranian specimens are intermediate between R. *peltatus* and *R. baudotii*, mainly the fruit peduncles, which are bended backwards, but not essentially elongated after flowering.

Taking into account the frequent occurrence of floating leaves in both of the new Iranian populations, the relatively short fruit peduncles (ca. 5 cm), the nearly semiglobose shape of the fruit receptacle and the fact, that MEIKLE (1959) already stated that the Eastern populations all show relatively small achenes (1.2–1.6 mm long), a determination as *R. peltatus* SCHRANK s.str. is well confirmed.

Examined specimens: **Iran**: Ardabil, 43 km on the road of Ardabil to Khalkhal, near to Neor lake, 2553 m a.s.l., 37°57'42" N, 048°33'10" E, 07 Aug. 2012, Naqinezhad & Bidarlord 3002 [MUH]; – East Azerbaijan, Bozqush Mts., between Nishagh and Ardaha villages, 2497 m a.s.l., 37°46'06" N, 047°41'19" E, 16 Jun. 2012, Noroozi 2693 [WU]; – E Azarbaijan, Mianeh, after Tark village, Nishag village, Bozgush Mt., 2500 m, 37°46'06"N, 47°41'14"E, 11.6.2015, J. Noroozi 3240 [W 2015-0015018!, W 2015-0015019!, G!, MSB!]; – province Åsårbåyjån-e Sharqi, 39 km N Miyaneh, Boz Ghoush mountains, 7.7 km N of Sorkeh Hesar, 37°46'01"N 47°41'12"E, 2500 m s.m., 11.6.2015, E. Vitek, J. Noroozi & H. Rainer 15-0127a [W 2015-0008587].

Nomenclatural remarks

To avoid future confusion, a list of used names and their synonyms is given.

Ranunculus peltatus group

***Ranunculus peltatus* SCHRANK**, Baier. Fl. 2: 103 (1789).
= *Ranunculus triphyllos* WALLR. (1840) [non auct. mult.].
= *Ranunculus floribundus* BAB. (1855).
= *Ranunculus dichotomus* (SCHMALH. ex TRAUTV.) N.I.ORLOVA (1956).
= *Ranunculus rhipiphyllus* BAST. ex BOREAU, Fl. Centr. Fr., ed. 3, 2: 11 (1857).
= *Batrachium langei* F. SCHULTZ ex NYM. (1878) [nom. nud.].
= *Ranunculus kastamonuensis* DÖNMEZ (2003) – fide PAROLLY & EREN (2007).

***Ranunculus saniculifolius* VIV.**, Florae Libycae Spec., 29, tab. 2, fig. 2 (1824), non SCHUR (1866).
=? *Ranunculus peltatus* SCHRANK subsp. *fucoides* (FREYN) MUÑOZ GARMENDIA (1985).

***Ranunculus baudotii* GODRON**, Mém. Soc. Roy. Sci. Nancy, 1839: 21 (1839).
= *Ranunculus carinatus* (SCHUR) SIMONK. (1887).
= *Ranunculus obtusiflorus* auct., non (DC.) MOSS (1914).

= *Ranunculus confusus* Godron in Gren. & Godron (1847).
= *Ranunculus drouetii* auct., non Godron (1848).
= *Ranunculus petiveri* auct., non Koch (1840).
= *Ranunculus marinus* (Fries) Hartman (1846).
=? *Ranunculus peltatus* Schrank var. *microcarpus* Meikle (1959).
Synonymy unclear, original statement by Meikle (1959: 15), "It resembles *R. confusus* Godron" (a form of *R. baudotii* Godron) … "but the leaves match those of *R. peltatus*" (while *R. baudotii* has the same floating leaf type as *R. peltatus*!).

Determination key for Iranian species of *Ranunculus* subgen. *Batrachium*

1 Aquatic plants with rooting shoots either completely submersed or apices floating up, with only flowers emerging the water body, with deeply dissected, capillary underwater leaves 3
1* Plants in a terrestrial modification, with a distinct terrestrial leaf type (capillary, resembling the underwater leaf type, but rigid with much shorter sections). Note that all parts of such plants, especially petals may be smaller and shorter compared with fully developed aquatic modifications 2

2 Petals non-overlapping, ephemeral, up to 4 mm long. Nectary (nectar pit) semilunar (bowl-shaped). Receptacle elongated, ovate, with numerous, (30–) 50–60 (–80) achenes. Only the terrestrial leaf type present ..... ***R. rionii*** (see 5)
2* Petals overlapping, persistent (for the whole flowering period), (5–) 6 (–8) mm long. Nectary (nectar pit) pyriform. Receptacle semiglobose, bearing not more than 40 achenes. Sometimes (but rarely) laminar (floating) leaves are followed by terrestrial leaves ..... . ***R. peltatus*** (see 3, 6)

3 Plants heterophyllous when flowering, beside the capillary underwater leaf type some laminar, trilobate floating leaves are present at the top of the shoots ..... ***R. peltatus*** (see 2, 6)
3* Plants homophyllous with only capillary underwater leaves, even when flowering 4

4 Flowers often submersed (regularly in running waters), mainly cleistogamic, petals separated, non-overlapping, ephemeral, up to 6 mm long. Nectary (nectar pit) semilunar (bowl-shaped) 5
4* Plants always flowering above the water surface, allogamic, petals overlaping, persistent for the whole flowering period, more than 8 mm long. Nectary (nectar pit) pyriform 6

5 Receptacle semiglobose, bearing not more than 40 achenes, single achene (1.2–) 1.3–1.5 (–1.7) mm long, hispid at their apex, even at maturity ..... ***R. trichophyllus***
5* Receptacle elongated with (30–) 50–60 (–80) achenes, single achene 1.0–1.2 (–1.3) mm long, glabrous at maturity (sometimes setose at their apices before maturity) ..... ***R. rionii***

6 Receptacle semiglobose to ovoid, bearing up to 40 achenes. Achenes ellipsoidic, 1.2–1.6 mm long*, often hispid at their apices, faintly ridged ..... ***R. peltatus*** (see 2, 3)
6* Receptacle elongated, bearing (30–) 50–80 (–100) achenes. Achene nearly spherical, up to 1 mm in diameter, glabrous, with prominent transversal ridges ***R. sphaerospermus***

* This is in accordance to Meikle's (1959) findings for Eastern populations, in Central Europe up to 2 mm and more!

Ecological preferences and distribution of *R. peltatus*

R. peltatus is frequently occurring in unbuffered, running or stagnant waters, even in high mountain localities throughout the area of the *R. peltatus* group. *R. saniculifolius* is commonly distributed in running or stagnant freshwater bodies in Mediterranean lowlands and *R. baudotii* is a species of mineralized or brackish water stands, along the European coastline and in some inland water stands.

The area of *R. peltatus* covers whole Europe, including most of the Mediterranean mountain regions, with isolated patches in the Atlas mountains of North Africa (in Morocco and Algerie), in the Near East (Palestine, together with the North African area patches the southernmost locations), Lebanon, Syria, and Turkey. Few records in Iran, among them the new localities, and one single outlier in Afghanistan, correctly assigned in this paper, are the easternmost locations.

Unravelling the complex synonymy in KRECZETOWICZ (1937), the eastern distribution limit of *R. peltatus* follows the Pechora river basin (western foothills of the Northern Ural, the northernmost locations) and the Caucasus region, omitting most of the Pontocaspian steppe region (Fig. 2).

Further new findings of isolated patches in the southern- and easternmost parts of the area, from the Mediterranean region and North Africa reaching to the Middle East may still be possible, but the patchy structure of these parts of the distribution area is well established.

The concept of remnants of Pleistocene refugia (HEWITT 1999) is widely accepted. But aquatic habitats are frequently changeable in their ecosystem characteristics in geological time scales (for example refer to FAUST & al. 2004) and not suitable for a long-time continuous colonization. Thus, these disjunct spots, contrasting to the uniform area in northern and western Europe, cannot be explained as local remnants of a Pleistocenic episodic southward extension of the distribution area.

As already noticed in ancient literatures (e.g. DARWIN 1860: 386) a most efficient way for distribution of aquatic organisms, macrophytes as well as animals is effected by water fowl populations on a regional scale and migrating water birds for long-distance distribution (SANTAMARÍA 2002). Propagules spread in this way may be vegetative shoots as well as seeds, and they may be transported either epizoochorously (VIVIAN-SMITH & STILES 1994) or endozoochorously (CLAUSEN & al. 2002, FIGUEROLA 2003). A successful dispersal may be a rare event, but possible at any time. The potential role and frequency of bird dispersal was discussed for example by GREEN & al. (2008) and CLAUSEN & al. (2002). Recently, this pathway was also established for water snails by VAN LEEUWEN (2012).

Nearly all of the places with patchy occurrence of *R. peltatus* are crossed by bird migration flyways (Fig. 2). The easternmost pathway of the western Palaearctic bird migration region (Northern Europe – Caspian region – Persian Gulf/Schatt al-Arab) directly crosses over the area of the new records (ELPHICK 2007), and bird dispersal will be most effective if propagules are spread unidirectionally, in this case from the Baltic and Scandinavian region (with rich stands of *R. peltatus*) during the southward autumn migration (CLAUSEN & al. 2002). Possible vectors are geese (*Anserinae*), storks (*Ciconiidae*) and the Eurasian crane (*Grus grus, Gruidae*) (ELPHICK 2007).

Migrating birds as long-distance vectors, following the same migration routes as described here are also known from the dispersal of H5N1 avian influenza disease

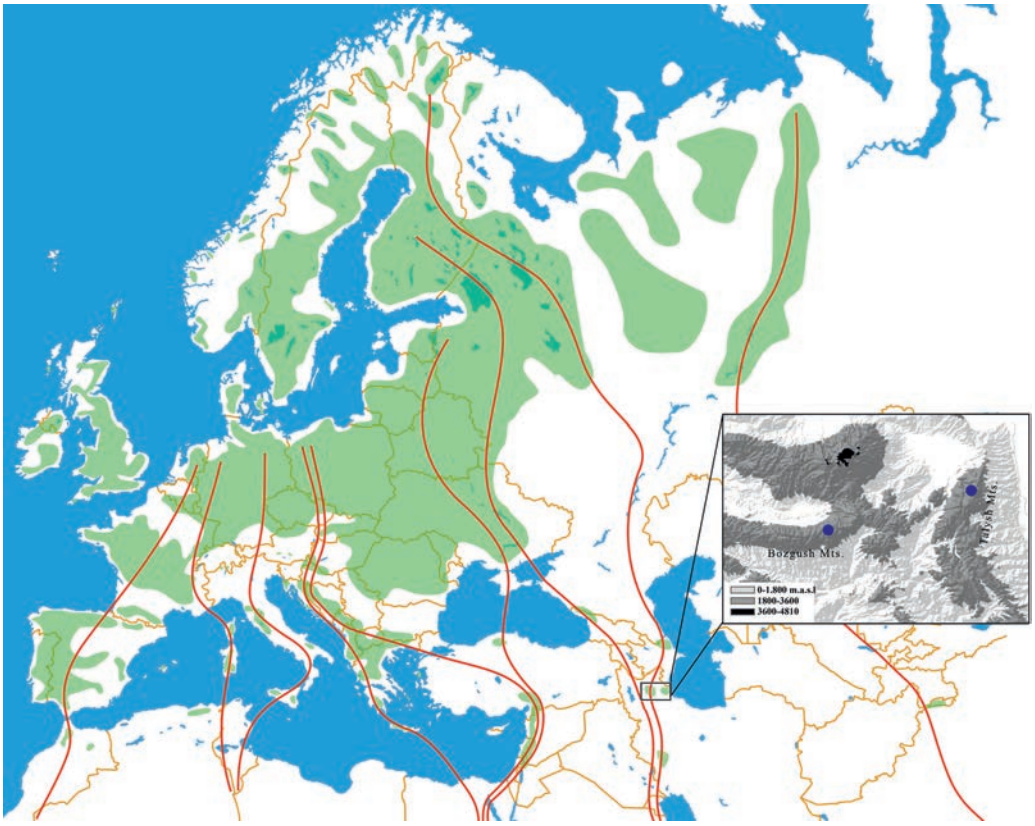

Fig. 2: Distribution of *Ranunculus peltatus* SCHRANK (green patches), newly compiled using data from COOK 1966, CASPER & KRAUSCH 1981, PRESTON & CROFT 1997 (GB), Tela Botanica (France), FloraWeb (Germany), National Biodiversity Network, IUCN Red List, unpublished data from the Mapping of the Middle European flora project (courtesy of H. Niklfeld, Vienna), KRECZETOWICZ 1937 (Russia and adjacent countries), MAIRE 1964 (Morocco and Algerie, if correctly identifiable), PIZARRO 1995 and CARRASCO & CASTILLO 1993 (Iberian peninsula), PIGNATTI 1982 (Italy), several papers of DAHLGREN et. auct. (Greece), PAROLLY & EREN 2007 (Turkey), MEIKLE 1959 (Palestine) and herbarium sheets from W and WU. Single records from sparsely explored landscapes (Northern Scandinavia and Russia) were expanded to the whole habitable areas (riverine corridors, wetland and lake areas) to give a reliable depiction. The main bird migration flyways (red lines) covering all the patchy southern occurrences are depicted after BUSSE & al. 2014, POPE & ZOGARIS 2012 and ELPHICK 2007. The two new Iranian localities are shown in the inserted topographic map.

(GILBERT & al. 2006) and from recent West Nile virus outbreaks in southern and Eastern Europe (RAPPOLE & al. 2000).

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