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Research Article

HABITAT PREFERENCES, DISTRIBUTION AND ANATOMY OF THE CLASPING-LEAVED PONDWEEDS OF TURKEY

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Abstract: Clasping-leaved *Potamogeton* L. species growing in Turkey are *P. praelongus* Wulfen and *P. perfoliatus* L. There exists no detailed study about distribution, habitat requirements, and anatomical properties of the Turkish populations of the two species. *Potamogeton perfoliatus* is widespread throughout the country but *P. praelongus* was recorded only from a single locality. Therefore, *P. praelongus* is rare and endangered in Turkey. In this study, we recorded presence of *P. perfoliatus* in 54 wetlands based on examination of 86 herbarium specimens. Physical and chemical parameters of the water bodies where the two species occur were measured from 24 sites for *P. perfoliatus* and from one site for *P. praelongus.* According to our findings, *P. praelongus* grows in an alpine lake with oligotrophic, calcareous and alkaline water. *Potamogeton perfoliatus* occupies diverse habitats but prefers deep lentic water bodies with high pH and low salinity levels. Stem anatomy of the species were studied based on three individuals for *P. praelongus* and 35 individuals for *P. perfoliatus*. Morphological features of the species were also investigated and descriptions based on Turkish material were prepared. We provided the distinguishing anatomical and morphological characters between the species. Our anatomical findings showed that *P. praelongus* specimens have eight vascular bundles in contrast to previous reports on the species. Our results can be used for future monitoring of the two submerged *Potamogeton* species as we provide detailed information about their current distribution pattern and habitat features.

Özet: Türkiye'de yetişen gövdeyi saran yapraklı *Potamogeton* L. türleri *P. praelongus* Wulfen ve *P. perfoliatus* L.'tur. Bugüne kadar bu türlerin dağılımı, habitat tercihleri ve anatomik özellikleriyle ilgili detaylı çalışmalar yoktur. *Potamogeton perfoliatus* ülke çapında yaygın bir türdür ancak *P. praelongus* sadece bir lokaliteden kaydedilmiştir. Bu nedenle *P. praelongus* Türkiye'de nadir ve tehdit altındadır. Bu çalışmada 86 herbaryum örneğine dayanarak *P. perfoliatus*'u 54 sulak alandan kaydettik. Türlerin yetiştiği suların fiziksel ve kimyasal parametreleri *P. perfoliatus* için 24 noktadan, *P. praelongus* için bir noktadan ölçülmüştür. Bulgularımıza göre, *P. praelongus* oligotrofik, kalkerli ve alkali alpin bir gölde yetişmektedir. *Potamogeton perfoliatus* çok farklı habitatlarda bulunmakla birlikte, yüksek pH, düşük tuzluluk değerlerine sahip, derin ve durgun suları tercih etmektedir. Türlerin gövde anatomileri *P. praelongus* için 3 birey, *P. perfoliatus* için ise 35 bireyden örnek alınarak incelenmiştir. Türlerin morfolojik özellikleri de araştırılmış ve Türkiye'den toplanan materyallere dayalı olarak betimler hazırlanmıştır. Türler arasındaki ayırt edici anatomik ve morfolojik karakterler verilmiştir. Anatomi bulgularımız *P. praelongus*'un önceki bazı çalışmalara aykırı olarak sekiz iletim demetine sahip olduğunu göstermektedir. Bu çalışmada türlerin güncel dağılım ve habitat tercihleriyle ilgili sunduğumuz kapsamlı bulgular iki batık *Potamogeton* türünün gelecekte izlenmesinde faydalı olacaktır.

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Introduction

Aquatic plants are primary producers and provide habitat and food to different organism groups, like algae, zooplankton, invertebrates, and different vertebrate taxa, such as fish and frogs (Bornette & Puijalon 2011). Additionally, they are very important for establishment and maintenance of healthy ecosystems as they improve water quality due to their filtering capacity of excessive nutrients. They also affect water flow and sediment properties. Nutrient content of waters is very important for the diversity of macrophytes. It is known that the highest macrophyte diversity can be seen under moderate nutrient levels, and extreme nutrient levels favor only certain species. Under very low nutrient levels, stress tolerant species manage to survive and under eutrophic conditions, very competitive species grow in high densities and replace other species (Bornette & Puijalon 2011). Therefore, macrophytes are very sensitive to habitat deteriorations mainly caused by anthropogenic

alterations. Aquatic plants have faced an increasing extinction risk in the last decades due to eutrophication, water regime changes, pollution and introduction of invasive exotic species (Guo *et al.* 2019).

Potamogetonaceae is one of the largest aquatic plant families of the world with approximately 100 species growing in very diverse habitats. *Potamogeton* L., one of the most ecologically important genera of all aquatic plants (Haynes 1985), has the highest number of species in the family with species having solely floating or submerged leaves and species with both submerged and floating leaves (Wiegleb & Kaplan 1998). The genus contains approximately 72 species and 99 hybrids (Kaplan *et al.* 2013). Taxonomy of the genus is quite difficult due to high number of hybrids and availability of limited reliable morphological characters (Wiegleb 1988). Additionally, *Potamogeton* species are known to exhibit extensive phenotypic plasticity, contributing to the difficulty of species delimitation.

First detailed taxonomical revision of *Potamogeton* was carried out by Ascherson and Graebner (1907) who divided *Potamogeton* into five sections and 13 subsections. Hagström (1916) published the most comprehensive study about *Potamogeton* including anatomical characters. Treatment of Hagström revealed five sections and 26 subsections. *Potamogeton praelongus* Wulfen (long-stalked or white-stemmed pondweed) belongs to the clasping leaved *Potamogeton* species group. Ascherson and Graebner (1907) evaluated *P. praelongus* and *P. perfoliatus* L. with submerged and clasping-leaved species in the subsection *Perfoliati* Graebner of section *Heterophylli* K. Koch. However, Hagström (1916) separated the clasping-leaved species into two subsections: Subsection *Perfoliati* (Graebner) Hagström and subsection *Praelongi* Hagström. Haynes (1985) followed Hagström's (1916) taxonomical treatment. More recently, Wiegleb (1988) recombined the two species in *P. perfoliatus* group.

Potamogetonaceae is the largest aquatic plant family in Turkey with 20 species and three hybrids belonging to five different genera (Uotila 1984, Aykurt *et al.* 2017, Bayındır 2018, Bayındır & İkinci 2020a, 2020b). As the largest genus within the family, *Potamogeton* is represented by 14 species and three hybrid in Turkey. *Potamogeton praelongus* was included in the Flora of Turkey (Uotila 1984) based on a single record in the Flora of Caucasus (Grossheim 1928) from Kars province of north eastern Turkey. Since then, it could not be collected again and was thought to be extinct in Turkey. Although we visited several herbaria to examine *Potamogeton* species, we could not find any *P. praelongus* specimens collected from Turkey. However, during our fieldworks in 2016, we collected *P. praelongus* from a second locality in southern Turkey (Fig. 1, Bayındır 2018). According to Vöge (1992), world distribution of *P. praelongus* is Nordic, weakly suboceanic, and circumpolar. In Europe, its distribution extends from northern Scandinavia to south of France in the Alps and in Pyrenees. The species is also distributed in similar latitudes of Asia and North America. Even though the species is distributed in a wide geographical area, it is still a rare species (Prausová *et al.* 2011). It is considered as endangered in Switzerland and in Germany (Vöge 1992) and as critically endangered in the Czech Republic (Prausová *et al.* 2011). In the UK it is considered as near threatened and it is a protected species in France (Julve 2017). Prausová *et al.* (2014) stated that *P. praelongus* is endangered in all Central Europe. However, IUCN assessed it as Least Concern (Lansdown 2014).

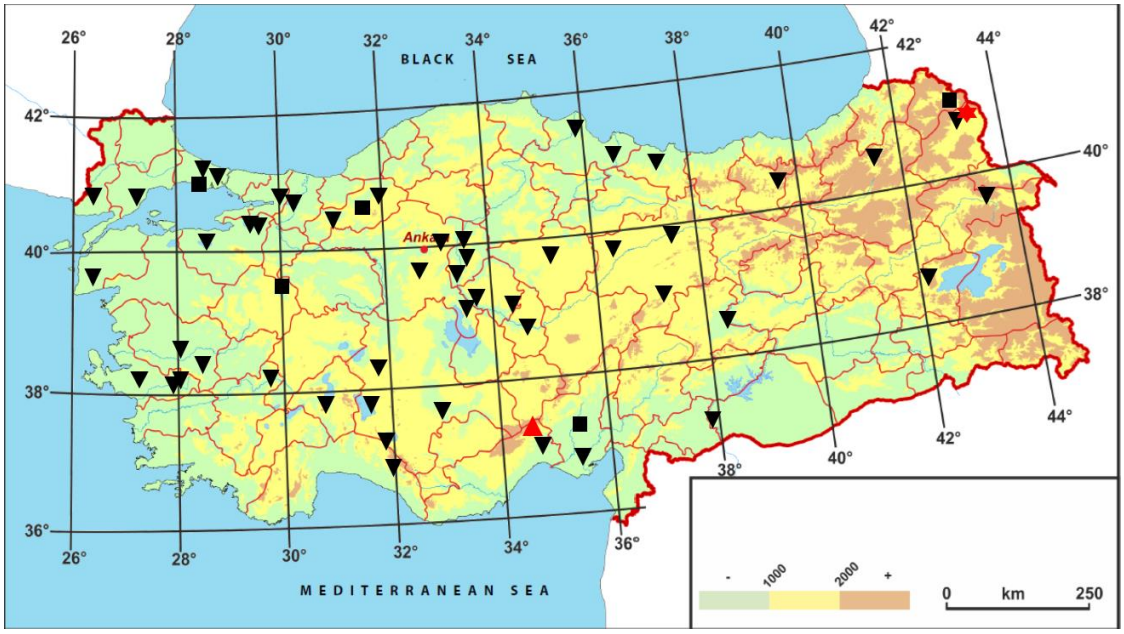

Fig. 1. Distribution map of *P. praelongus* (▲current location, ★ historical location) and *P. perfoliatus* (▼according to Bayındır (2018) and ■ new collection sites added with this study) in Turkey. Revised from Bayındır (2018).

Potamogeton perfoliatus is the other clasping leaved species in Turkey and is widespread throughout the country except the southeastern Anatolia. This region of Turkey has a hot and semi-arid climate with semi-arid steppe vegetation different from the rest of the country (Ergüner *et al.* 2019). According to Gupta & Lansdown (2013), *P. perfoliatus* can be considered a cosmopolitan species as it has a distribution throughout Eurasia (from the Mediterranean to northern Scandinavia and Iceland, Siberia), in North America and Greenland, in North and Central Africa and in Australia. It is assessed as Least Concern (LC) by IUCN (Gupta & Lansdown 2013). Haynes (1985) stated that *P. perfoliatus* is a morphologically very variable species. Therefore, several subspecific categories were defined for the species. However, these variations are mainly on vegetative characters and do not require distinct taxonomic divisions (Haynes 1985).

Studies on *P. perfoliatus* are mainly restricted to floristic records and altitudinal distribution analysis (Bayındır 2018, İkinci & Bayındır 2019, İkinci & Bayındır 2020) and there exist no study about the anatomy and habitat requirements of the species in Turkey. Therefore, we aimed in this study i) to provide detailed information about the geographical distribution of the clasping-leaved *Potamogeton* species in Turkey, ii) to determine the habitat features of the species including water chemistry and other environmental parameters, iii) to prepare new morphological descriptions of the species based on Turkish material and v) to provide morphological and anatomical comparisons between *P. praelongus* and *P. perfoliatus*.

Materials and Methods

Plant Materials

The plant material was collected from the field between 2014 and 2017 as a part the project on the revision of Potamogetonaceae family in Turkey. Entire plants were taken from fresh material in the field and preserved in 70% alcohol solution for anatomical studies which are stored at Bolu Abant İzzet Baysal University Herbarium (AIBU) (Table 1). Herbarium specimens were also prepared for each sample and stored in AIBU. Additionally, the following herbaria were visited to study the *Potamogeton* species: ANK, ISTE, ISTF, HUB, ISTO, ADA, K, E, L, LINN, VANF (acronyms according to Thiers 2016).

Environmental Parameter Measurements

Physical and chemical parameters of the water bodies where the two *Potamogeton* species were sampled were measured from 25 different wetlands during the growth season of the plants in 2016 and 2017. We sampled the plants and physical and chemical properties of the water from the littoral zone of water bodies. In deeper sites, we gathered macrophytes with the help of a rake. Single measurements were made per site for physical and chemical variables. We measured seven environmental variables with a portable multi probe YSI-Professional Plus in situ. The environmental variables were dissolved oxygen concentration (DO, mg l^{-1}), water temperature (Tw, °C), electrical conductivity (EC, µS cm^{-1}), pH, total dissolved solids (TDS, g l^{-1}), salinity (ppt) and ammonium (mg l^{-1}). The altitudes of the sampling sites were recorded by using Magellan eXplorist 610. Environmental variables and abundances were measured at random locations where the species were collected. We estimated abundance visually and recorded the percentage area covered by each species. Abundance percentage measurements were based on ACFOR scale [abundant (>80% cover), common (61–80%), frequent (31–60%), occasional (5–30%), and rare (<5%)] (Crisp & Southward 1958, Dunham et al. 2018). The estimated values were converted to numerical scores from 1 to 5. We also recorded the accompanying aquatic plant species (Table 1).

Table 1. List of our collections for *P. perfoliatus* with information about other accompanying Potamogetonaceae species.

Locality	Coordinates	Altitude (m)	Date	Anatomy material	*P. perfoliatus*	*P. lucens*	*S. pectinata*	*G. densa*	*P. natans*	*P. crispus*	*P. berchtoldii*	*P. gramineus*	*Z. palustris*	*P. nodosus*	*P. pusillus*	*P. trichoides*
*Adana: Seyhan Dam Lake	37.04921 N, 35.31672 E	59	27.vi.2016	√	+	+	+									
Antalya: Gündoğmuş, Lake Eğil	36.93217 N, 32.19954 E	2078	25.vi.2016	√	+	+		+	+							
* Ardahan: Güvenocak, Çıldır Lake	41.09930 N, 43.24034 E	1959	11.vii.2017	-	+		+			+						
* Bolu: Gölköy Lake	40.42'06 N, 31.31'09 E	770	02.ix.2014 14.vii.2014	-	+	+	+	+		+	+	+	+			
Bolu: Yeniçağa Lake, S. of the lake	40.77353 N, 32.02366 E	989	13.vii.2015	√	+						+					

Table 1. continued.

Locality	Coordinates	Altitude (m)	Date	Anatomy material	*P. perfoliatus*	*P. lucens*	*S. pectinata*	*G. densa*	*P. natans*	*P. crispus*	*P. berchtoldii*	*P. gramineus*	*Z. palustris*	*P. nodosus*	*P. pusillus*	*P. trichoides*
Bursa: İznik Lake, near wharf	40.47785 N, 29.66242 E	85	29.vii.2015	√	+											
Bursa: İznik Lake	40.44677 N, 29.71397 E	87	29.vii.2015	√	+		+			+			+			
Bursa: İznik Lake, Boyalıca	40.48302 N, 29.56499 E	83	29.vii.2015	√	+											
Bursa: Ulubat Lake, bird watching pier	40.19893 N, 28.44291 E	1	30.vii.2015	√	+					+						
Denizli: Çivril, Işıklı Lake, entrance to Beydilli	38.25761 N, 29.93300 E	827	19.vi.2016	√	+	+	+			+						
Edirne: Enez, W. of Gala Lake	40.75159 N, 26.16873 E	34	12.vi.2016	√	+		+			+				+		
Erzurum: Uzundere, 2 km to Tortum Dam	41.57944 N, 41.60204 E	1018	19.viii.2016	√	+		+				+					
Gümüşhane: Erzincan-Bayburt Road, Salyazı Dam	40.24449 N, 39.81048 E	1684	20.viii.2016	√	+		+					+				
İstanbul: Arnavutköy, Terkos Lake	41.37284 N, 28.56756 E	2	10.viii.2016	√	+	+									+	
* İstanbul: Büyükçekmece, Büyükçekmece Lake	41.06745 N, 28.57156 E	-1	10.vi.2016	√	+										+	
İstanbul: Eyüp, Göktürk, Göktürk Dam Lake	41.19319 N, 28.87544 E	41	10.vi.2016	√	+				+	+	+					+
İzmir: Torbalı, Torbalı Dam Lake	38.17277 N, 27.16007 E	63	20.vi.2016	√	+					+	+					
Kars: Doğruyol, Çıldır Lake	41.06916 N, 43.32759 E	1960	11.viii.2017	-	+		+								+	
Kırıkkale: Ankara border, Kızılırmak River	39.93968 N, 33.41290 E	661	22.viii.2016	-	+		+						+			
Kırıkkale: Keskin, Köprüköy, Kapulukaya Dam	39.57404 N, 33.43205 E	719	05.ix.2016	√	+			+					+			
Kırşehir: Mucur, near Karkın Village, Kargın Dam Lake	39.00823 N, 34.48361 E	1086	05.ix.2016	√	+		+			+	+					
Konya: Bozkır, Dipsizgöl	37.10161 N, 32.04097 E	1687	08.ix.2016	√	+					+				+		
Konya: Ilgın, Çavuşçu Lake	38.37327 N, 31.89334 E	1016	08.ix.2016	-	+							+				
Konya: Çumra, Türkmenkarahüyük Village	37.61108 N, 33.02601 E	992	08.ix.2016	√	+											
* Kütahya: Eskişehir-Kütahya Road, Sofça Village, Porsuk Dam	39.60567 N, 30.14925 E	895	18.vi.2016	√	+		+				+		+			

Table 1. continued.

Locality	Coordinates	Altitude (m)	Date	Anatomy material	*P. perfoliatus*	*P. lucens*	*S. pectinata*	*G. densa*	*P. natans*	*P. crispus*	*P. berchtoldii*	*P. gramineus*	*Z. palustris*	*P. nodosus*	*P. pusillus*	*P. trichoides*
Mersin: Tarsus Dam Lake	36.95359 N, 34.89384 E	35	27.vi.2016	√	+		+			+				+		
Ordu: Fatsa, Sefaköy, Gaga Lake	40.75159 N, 26.16873 E	67	15.viii.2016	√	+									+		
Sakarya: Sapanca Lake, Eşme Village shores	40.73328 N, 30.23521 E	26	29.vii.2015 15.viii.2015	√	+	+								+		+
Samsun: Ayvacık, Suat Uğurlu Dam Lake	41.07370 N, 36.66831 E	53	14.viii.2016	√	+		+									
Samsun: Delta Kızılırmak, bird sanctuary	41.67075 N, 36.03464 E	3	14.viii.2016	√	+		+							+		
Sivas: Hafik, Hafik Lake	39.87247 N, 37.38256 E	1269	21.viii.2016	√	+		+									
Sivas: Halkaçayır Village, Dam Lake	39.80974 N, 36.34908 E	1372	21.viii.2016	√	+											+
Tekirdağ: Yazır Dam Lake	40.92561 N, 27.40341 E	59	12.vi.2016	√	+		+			+				+		
Yozgat: Entrance to Sorgun, Mükremin Pond	39.80372 N, 35.21713 E	1076	21.viii.2016	√	+		+									
Total (34 wetlands)				29	36	6	18	3	2	12	7	3	5	7	3	3

* New wetlands added to the list in Bayındır (2018).

Anatomical studies

Plant samples were taken to represent all parts of the plants for morphological diagnosis and samples preserved in 70% alcohol solution were used for subsequent anatomical studies. Stem anatomy samples were prepared from three individuals for *P. praelongus* and from 35 individuals for *P. perfoliatus*. The internode areas of stems of the specimens were cut about 0.05 mm thick with the aid of razor blades. Samples were put into safranin or toluidine blue dye and transferred to distilled water. Stem fragments were examined under the light microscope at 4x, 10x and 40x magnifications. The stele types, shape of endodermal cells, pseudohypodermis, presence of subepidermal bundles and interlacunar bundles in the cortex were determined and photographed.

Results

Potamogeton praelongus Wulfen

Description

Stem slightly branched or unbranched with rhizome; terete; clearly zig-zag shaped; mostly white or pale green, up to 200 cm in length. Leaves sessile, all submerged, alternate, lax, mostly undulate or entire, pale green to olive green, lanceolate to broadly lanceolate, broadly ovate elliptic, 11-17 veined, midrib without lacunae, 52-171 x 14-27 mm, margin entire, at base cuneate and semiamplexicaule, at apex clearly cucullate, (splitting when pressed), obtuse. Stipules persistent, conspicuous, convolute, free from blade, white, 17-42 mm, fibrous.

Locality

TURKEY, Mersin, Çamlıyayla, Darboğaz, near Summit Medetsiz, Karagöl Lake, 2591 m, 37.404261 N, 34.559753 E, 07 September 2016, N. Bayındır 1360 (AIBU 12735) (Fig. 1).

Table 2. Water chemistry measurements for *P. praelongus* (see materials and methods for abbreviations).

Tw (°C)	pH	DO (mg l^{-1})	EC (µS cm^{-1})	TDS (g l^{-1})	Salinity (ppt)	Ammonium (mg l^{-1})
17.9	7.86	5.92	165.9	0.1248	0.09	0.02

Ecological notes

Potamogeton praelongus was collected from an oligotrophic, calcareous, snow-melting lake (Karagöl Lake) with alkaline water (Table 2). In addition to *P. praelongus*, *P. natans* L., *Stuckenia filiformis* (Persoon)

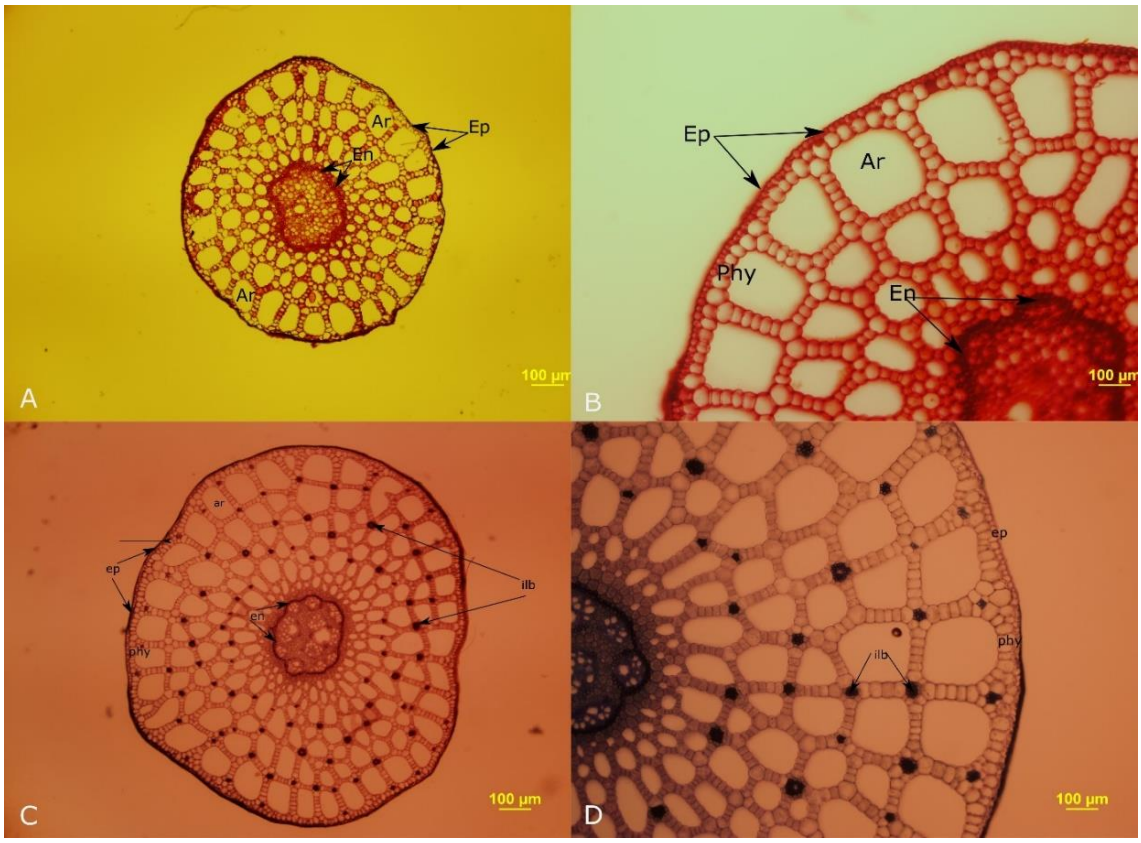

Fig. 2. Stem anatomy of *P. perfoliatus* (A, B) and *P. praelongus* (C, D). General view (A, C) (4×), Epidermis and cortex (B, D) (10×), (Ar: aerenchyma, En: endodermis, Ep: epidermis, Ilb: interlacunar bundle, Phy: pseudohypodermis).

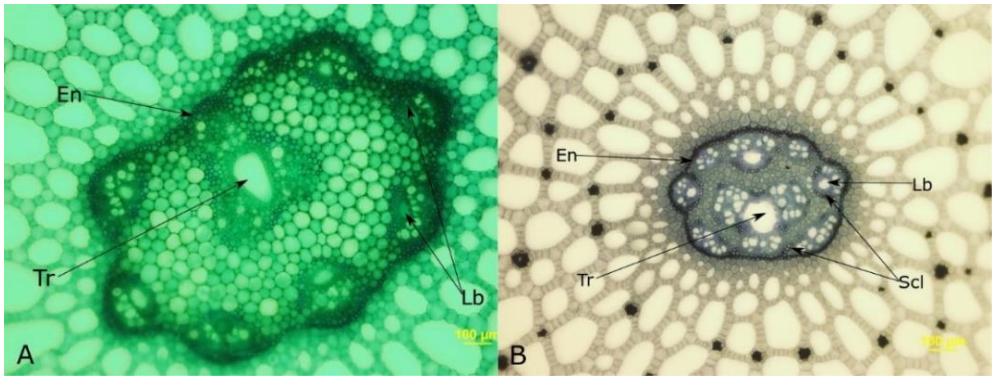

Fig. 3. Stele of *P. perfoliatus* (A) and *P. praelongus* (B) (10×), (En: endodermis, Lb: lateral bundle, Scl: sclerenchyma, Tr: trio-bundle).

Börner, *Persicaria amphibia* (L.) Gray were growing in the lake. Since the species is currently known only from this site in Turkey, we have single measurements of the physical and chemical parameters of the water body where the species was sampled.

Anatomy

Our anatomical findings for *P. praelongus* and *P. perfoliatus* are shown in Figs 2-3 and Table 3.

Potamogeton perfoliatus L.

Description

Stem slightly unbranched or branched at the top with rhizome; terete; dark green, pale green, whitish or brownish upto 200 cm length; without turion. Leaves sessile, all submerged, alternate, undulate or entire, usually olive-green, rarely dark green, rarely leaves with rusted colour, broadly lanceolate, broadly ovate or close to rounded, 5-25 veined, midrib without lacunae, 17-61 × 12-34 mm, margin slightly denticulate, at base cordate and amplexicaul, at apex mostly entire or slightly cucullate, obtuse, rounded or acute. Stipule free from blade, convolute, mostly deciduous rarely persistent, ca. 14 mm long, nonfibrous. Inflorescence spike, terminal, sometimes axillary, cylindrical, 19-27 mm long, continuous; flowers dense. Carpels 4. Fruits sessile, obovate, 2.5-3.5 × 1.8-2.25 mm; beak short, dark green to blackish, 0.3-0.5 mm long.

Table 3. Comparison of anatomical characters of *P. praelongus* and *P. perfoliatus* based on our collections.

Character	*P. praelongus*	*P. perfoliatus*
Stele types	Trio type	Trio type
Shape of endodermal cells	U type	O type
Pseudohypodermis	1 seriate	1 seriate
Presence of subepidermal bundles	Present	Absent/rarely present
Presence of interlacunar bundles in the cortex	Present	Absent/rarely present

Additional herbarium specimens examined

The information of the examined specimens at different herbaria are given in the below list. The list was organized in alphabetical order based on the names of the Turkish provinces (in bold). There are more than one herbarium specimens from the same wetland. The herbarium acronyms are in parenthesis.

Examined material: **Adana:** Yenice irrigation, main canal, G. Altınayar (DSI 1988). **Ağrı:** Balık Lake shores, 2210 m, 12 vi 1979, A. Baytop, B. Çubukçu (ISTE 42741). Balık Lake, 2261 m, 29 ix 2014, M.M. Uma, M. Kaya (AIBU). Suluçem (Musun), S. end of Balık Lake, 2300 m, shallow water, 23 vii 1967, P.H. Davis 47279 (K). **Ankara:** Bala, Kesikköprü Dam Lake, 790 m, 12 vii 2014, A.E. Yaprak, S.T. Körüklü, İ. Başköse, A. Güleryüz (AIBU, ANK). Elmadağ, 14 vii 1939, B. Kasaplıgil (ISTF 572). Eymir Lake, 08 vii 1933, W. Kotte (ANK). **Bitlis:** Nazik Lake shores, submerged, ca. 1870 m, 31 viii 1993, L. Behçet 4691 (VANF). **Bolu:** Abant Lake, 08 viii 1970, A. and T. Baytop (ISTE 18397). Yeniçağa Lake, near Gerede, 03 x 1961, A. and T. Baytop (ISTE 6882). **Bursa:** İznik, İznik Lake, ca. 85 m, 20 vii 1981, P. Uotila (EGE 24903). **Çanakkale:** Ayvacık, Creek Geme, 243 m, 03 ix 2014, E. Cabi, M.M. Uma, N. Albayrak (AIBU). **Denizli:** Çivril, W. of Işıklı Lake, Buca Village, ca. 850 m, 15 vi 1981, E. Leblebici (EGE 26217). **Edirne:** Enez, Gala Lake, G. Altınayar (DSI 1988). **Isparta:** N. of Eğirdir Lake, Hayran, ca. 940 m, 09 vii 1980, E. Leblebici (EGE 26841). **İstanbul:** Terkos Village, in the lake, 29 ix 1969, A. Baytop (E 00330333). Çatalca, Terkos Lake, 01 ix 1943, B. Kasaplıgil (ISTF 5282). Kurtköy, Terkos Lake shore, 04 x 1967, A. Baytop, G. Atila (ISTE 12146). Terkos Village, in the lake, 29 ix 1967, A. Baytop (ISTE). Terkos Lake, 29 vii 1952, A. Baytop (ISTE 2835). Terkos Lake, 02 vii 1969, A. Baytop (ISTE 15527). Terkos Lake, 17 vii 1970, A. Baytop (ISTE 18182). **İzmir:** Ödemiş, Bozdağ, Gölcük, 04 vii 1966, C. Regel (EGE 24864). Ödemiş, Gölcük, submerged, 07 vii 1962, C. Regel (EGE1851). Ödemiş, road to Gölcük, 08 vi 1946, A. Heilbronn, M. Başarman (ISTF). Ödemiş, Bozdağ Village, Kırkoluklar fountain, ca. 1000 m, 09 vi 1980, E. Leblebici (EGE 2680). **Kars:** Çıldır-Kars road, Lake Çıldır shore, 20 viii 1975, A. Baytop, E. Tuzlacı (ISTE 33416). **Kırıkkale:** Before Kızılırmak-Balaban stream mixing site, 678 m, 27 ix 2014, A.E. Yaprak, S.T. Körüklü, İ. Başköse, A. Güleryüz (AIBU, ANK). **Kırklareli:** City centre, Koyunbaba Village, Koyunbaba spring, submerged, 170 m, 24 v 1994, E. Üzen (ISTF). **Kırşehir:** Hirfanlı Dam, 875 m, 12 vii 2014, A.E. Yaprak, S.T. Körüklü, İ. Başköse, A. Güleryüz (AIBU, ANK). **Kocaeli:** Saracoğlu Motel at the Lake Sapanca, floating on the shore of the lake, 40 m, 01 ix 1972, P. Uotila 20153 (E). **Sakarya:** E. shores of Lake, near Arifiye, 04 vii 1976, A. Baytop, K. Alpınar (ISTE35123). N. shore of Sapanca Lake, 24 viii 1973, H. Güner (EGE12774). Sapanca Lake, 50 m, edge of lake, 30 vi 1962, P.H. Davis 36207, M.J.E. Coode (K). **Konya:** Akşehir, E. of Ilgın Village, Gedikören Village, ca. 1000 m, 08 vii 1980, E. Leblebici (EGE 26830). Ilgın, Çavuşçu Lake, submerged, 08 viii 1992, A.A. Dönmez, N. Emir (GAZI, HUB). Between Beyşehir-Şarkıkaraağaç, 12 km to Beyşehir, in water, 1100 m, 03 viii 1978, A. Baytop, E. Tuzlacı (ISTE41432). Beyşehir, Çiftlikköy, shores, 06 vii 2014, T. Körüklü (AIBU 12345). Beyşehir, 01 vi 1949, İ. Baykal (ISTF). Beyşehir (Isawia), Hoynan, in the lake, 05 viii 1949, P.H. Davis 16113 (K). Çumra irrigation canal, Yeni İsmil reserve irrigation canal, G. Altınayar (DSI 1988). **Malatya:** Karakaya Dam, 690 m, 19 vii 2014, M.M. Uma, N. Albayrak (AIBU). **Manisa:** Adala irrigation canal to Marmara Lake, G. Altınayar (DSI 1988). Salihli, N. of Gölmarmara, Sazköyü, ca. 90 m, 03 vi 1981, E. Leblebici (EGE26144). **Nevşehir:** Kızılırmak-Gülşehir Bridge, 888 m, 13 vii 2014, A.E. Yaprak, S.T. Körüklü, İ. Başköse, A. Güleryüz (AIBU, ANK). **Ordu:** Kaga Göl above Fatsa, 250 m, deep warm lake, 21 vii 1965, C. Tobey 1312 (E). **Samsun:** Bafra, Kızılırmak, 8 m, 08 vii 2014, A.E. Yaprak, S.T. Körüklü, İ. Başköse, A. Güleryüz (AIBU, ANK). **Sivas:** Kangal, Üçöz Dam Lake, 1573 m, 19 vii 2014, M.M. Uma, N.Albayrak (AIBU). **Şanlıurfa:** Birecik Dam Lake, 392 m, 24 vii 2014, M.M. Uma, N. Albayrak (AIBU). **Van:** Between Doğubeyazıt and Taşlıçay, Balık Lake, ca. 2450 m, 11 viii 1985, L. Behçet (VANF).

Ecological notes

Measurements of the physical and chemical parameters of the water bodies for *P. perfoliatus* were performed in 24 wetlands (Table 4). Unlike *P. praelongus*, *P. perfoliatus* is widespread and occurs in diverse habitats. The pH range of the water it occurs ranges from 7.52 to 9.01. Based on our collections from 34 wetlands, *P. perfoliatus* occurs together with other Potamogetonaceae species in 31 of these wetlands (Table 1). According to these findings, *P. perfoliatus* co-occurs in 18 wetlands with *Stuckenia pectinata* (L.) Börner, in 12 wetlands with *P. crispus* L., in 7 wetlands with *P. nodosus* Poir. and *P. berchtoldii* Fieber, in 6 wetlands with *P. lucens* L., and in 5 wetlands with *Zannichelia palustris* L., *Groenlandia densa* (L.) Fourr., *P. gramineus* L., *P. pusillus* L. and *P. trichoides* Cham. & Schltdl. were found to accompany *P. perfoliatus* in 3 wetlands. *Potamogeton natans* was found to grow together with *P. perfoliatus* at 2 sites and in 3 sites *P. perfoliatus* was the only species growing.

Table 4. Physical and chemical measurements for *P. perfoliatus* (NB stands for collector N. Bayındır. See materials and methods for additional abbreviations). Detailed information about each voucher is given in Table 1.

Voucher	Sampling date	Tw (°C)	pH	DO (mg l^{-1})	EC µS cm^{-1}	TDS (g l^{-1})	Salinity (ppt)	Ammonium (mg l^{-1})	Abundance
NB 1178	10.6.2016	22.1	8.28	5.64	427.8	0.2944	0.22	0.50	3
NB 1182	10.6.2016	23.6	8.49	8.48	309.9	0.2067	0.15	0.14	2
NB 1185	10.6.2016	25.9	8.31	10.56	710.0	0.4615	0.34	0.38	4
NB 1208	12.6.2016	27.6	7.53	3.98	2253	1.4040	1.10	1.11	1
NB 1216	18.6.2016	24.7	8.86	9.03	550.0	0.2675	0.27	0.72	3
NB 1228	19.6.2016	28.0	8.99	5.83	317.7	0.1911	0.12	0.32	4
NB 1235	20.6.2016	31.2	8.82	12.31	369.3	0.2080	0.15	0.42	4
NB 1261	25.6.2016	23.1	8.09	6.95	241.3	0.1631	0.12	0.26	4
NB 1268	27.6.2016	18.4	7.57	8.99	259.0	0.1924	0.14	0.39	3
NB 1273	27.6.2016	29.5	8.23	6.35	455.2	0.2723	0.20	0.21	2
NB 1293	14.8.2016	23.9	7.73	7.53	1977	1.3130	1.03	0.59	2
NB 1296	14.8.2016	24.1	8.24	7.64	415.5	0.2750	0.20	0.21	1
NB 1301	15.8.2016	26.8	7.88	3.66	350.1	0.2223	0.16	0.14	1
NB 1312	19.8.2016	17.1	7.52	6.40	470.0	0.3601	0.27	0.48	2
NB 1318	20.8.2016	23.0	8.13	5.96	253.7	0.1716	0.12	0.27	3
NB 1330	21.8.2016	23.2	7.77	3.52	2385	1.5065	1.27	0.11	3
NB 1335	21.8.2016	22.7	8.90	3.35	411.0	0.2802	0.21	0.11	2
NB 1337	21.8.2016	24.5	9.01	8.89	493.1	0.3237	0.24	0.22	2
NB 1339	22.8.2016	21.2	7.82	6.78	1595	1.1180	0.87	0.66	1
NB 1341	05.9.2016	17.4	7.60	6.37	974	0.7410	0.57	0.46	2
NB 1345	05.9.2016	22.2	8.33	4.38	547	0.3770	0.28	0.21	2
NB 1363	08.9.2016	21.9	8.03	6.55	432.3	0.2963	0.22	0.84	3
NB 1367	08.9.2016	22.1	7.97	4.83	304.6	0.2100	0.15	0.04	2
NB 1415	11.8.2017	22.0	8.65	7.91	133.3	0.0917	0.07	0.18	2

Discussion

There are two clasping-leaved *Potamogeton* species growing in Turkey (Uotila 1984, Bayındır 2018). Until recently, *P. praelongus* was thought to be extinct in the country. However, we collected the species from a new location different from that of the historical site in 2016 (Bayındır 2018). Our field observations in the historical site showed that the *P. perfoliatus* is the only species growing here. We identified all recent collections from this historical locality cited in the Flora of Caucasus (Grossheim 1928) as *P. perfoliatus*. It can be considered that the specimens were incorrectly identified as *P. praelongus* in the past. The other possibility is the replacement of *P. praelongus* from the lake by *P. perfoliatus*. Our recent collection site for *P. praelongus* is from southern Turkey where *P. perfoliatus* does not co-occur (Fig. 1). As indicated previously, *P. praelongus* has a widespread distribution range throughout temperate Northern Hemisphere. However, it is a very rare species in several of the countries it occurs and listed as endangered, critically endangered or near threatened. In several countries, its populations are declining. In Turkey, the species grows in a Mediterranean mountain habitat in an oligotrophic alpine lake at c. 2600 m (Bayındır 2018). This is the single population for Turkey and the only record for the species in the Mediterranean basin. Distribution range of the population is less than 500 m^2. Around the lake where *P. praelongus* grows, there are camping areas for mountain climbers and other tourists. The nearest settlement is 300 m below the lake, which is used as a summer pasture by villagers for stock farming. Increasing visitors will lead to increased eutrophication of the lake. The species is known to be very sensitive to

eutrophication and was recorded to disappear in some lakes due to increased eutrophication. Therefore, its unique population is subjected to rapid deterioration due to eutrophication and future climate changes. *Potamogeton praelongus* is a possible candidate to be negatively affected by global warming due to increase in surface water temperatures since its population is already at 2600 m (İkinci & Bayındır 2020). Urgent conservation strategies should be developed for the species to protect its current habitat. In terms of water chemistry preferences, in a study performed throughout Japan, Kadono (1982) found that *P. praelongus* has a pH range between 7.1 and 7.8 and EC range between 77 and 112 ($\mu S\ cm^{-1}$). We recorded slightly higher EC levels but our pH measurements fall within the range of this study. *Potamogeton praelongus* grows in waters with low EC, low salinity and low ammonium concentrations (Table 2). These are expected results since the alpine lake is mainly fed by snowmelt and rainwater. Other macrophytes occurring in the same lake are *P. natans*, *Stuckenia filiformis* and *Persicaria amphibia*. Among these species, *S. filiformis* is also very rare in Turkey and has only one additional record from Eğrigöl Lake in Antalya at 2060 m altitude. Different studies classify Eğrigöl Lake as either oligotrophic or oligo-mesotrophic (Kaymakçı-Başaran & Egemen 2006, Aygen *et al.* 2009). On the other hand, *P. natans* is a widespread species throughout Turkey with a tendency of preferring higher altitudes (İkinci & Bayındır 2020). *Persicaria amphibia* is a very widespread species having natural distribution range as northern circumpolar temperate but it is naturalized in North and South America, and South Africa (Partridge 2001). It is also a very common species in Turkey (Seçmen & Leblebici 2008, İkinci & Bayındır 2019). It can be found in different habitats including disturbed ones. It is not found in fast flowing water bodies. The species has adaptation to water level fluctuations because it has both aquatic and terrestrial forms (Partridge 2001). *Persicaria amphibia* occurs in a wide range of altitude and it was also found at higher altitudes in the Himalayas similar to Turkish population mentioned in our current study (Ram *et al.* 1989).

Potamogeton perfoliatus has almost a cosmopolitan distribution in the world (Gupta & Lansdown 2013). In Turkey, we found records of the species from 54 wetlands based on examination of 86 herbarium specimens (Fig. 1). In addition to the recent Illustrated Flora of Turkey (Bayındır 2018), we added 5 new wetlands for the distribution of the species based on our collections (Table 1). Therefore, we can better understand the extent of occurrence of *P. perfoliatus* in Turkey. The species has a broad altitudinal distribution from sea level to 2450 m but majority of collections are below 1200 m (İkinci & Bayındır 2020). Water chemistry measurements were performed from 24 sampling sites for the species (Table 4). It grows in water bodies with high pH levels. Majority of the collection sites are inland freshwaters. However, we recorded the highest salinity from an inland lake (Hafik Lake) in Sivas. We found the species in lakes and canals close to the Black Sea and the Aegean Sea but still with low salinity levels (max. 1.10 ppt). These findings are parallel to previous reports about *P. perfoliatus* (Burns *et al.* 1995). According to Twilley *et al.* (1985), *P. perfoliatus* grows in oligohaline to mesohaline waters. We recorded *P. perfoliatus* mainly from lentic habitats, out of 54 wetlands only seven were fast flowing rivers and canals. Our collection sites for the species were not shallow waters because the submersed broad-leaved species generally cannot tolerate drawdowns. When we analyzed the other accompanying Potamogetonaceae species provided in Table 1, we see the highest co-occurrence with *Stuckenia pectinata* in 18 wetlands. *Stuckenia pectinata* is the most widespread Potamogetonaceae species in Turkey which we sampled from 65 wetlands (İkinci & Bayındır 2020). Other species with the highest number of co-occurrences with *P. perfoliatus* are *P. crispus*, *P. nodosus*, and *P. berchtoldii*, respectively. These are also common species which we collected from more than 30 wetlands in Turkey (İkinci & Bayındır 2020). On the other hand, *P. natans* was sampled only in two common wetlands with *P. perfoliatus* (Table 1). We collected *P. natans* from 11 wetlands in Turkey which are mainly above 1200 m, indicating a clear difference in altitudinal preference compared to *P. perfoliatus* (İkinci & Bayındır 2018). The other interesting result is that *P. perfoliatus* were not found in water bodies where seven rare Potamogetonaceae species are growing (Bayındır 2018, İkinci & Bayındır 2020).

There are clear morphological and anatomical differences between *P. praelongus* and *P. perfoliatus*. Zig-zag shaped stem, cucullate leaf apice, leaf base, leaf margins and conspicuous, long, persistent stipule, presence of interlacunar bundles, subepidermal bundles and shape of endodermal cells in stem discriminate two clasping-leaved *Potamogeton* species (Table 3 and 5). Persistence of the stipule is an important character in the identification of *Potamogeton* species. In the newly collected *P. praelongus* specimens, stipules are persistent until the late stages of plants life cycle. However, in *P. perfoliatus* specimens we collected stipules decay early during the developmental stages of the plants and therefore are not persistent (Table 5). Previous studies indicated that leaf length is clearly longer in *P. praelongus* (Hagström 1916, Ogden 1943, Haynes 1985, Wiegleb & Kaplan 1998). In our samples, we measured maximum leaf length as 170 mm for *P. praelongus* and as 61 mm for *P. perfoliatus* (Table 5).

Table 5. Comparison of morphological characters of *P. praelongus* and *P. perfoliatus* based on our collections and former reports on the two species.

		Character				
		Stem	**Leaf base**	**Leaf apice**	**Stipule**	**Maximum leaf lenght (mm)**
This study	*P. praelongus*	Zig-zag	Semiamplexicaule	Cucullate	Conspicuous, long, persistent	170
	P. perfoliatus	Straight	Amplexicaul	Rarely cucullate	Nonpersistent	61
Hagström (1916)	*P. praelongus*	-	Hooded	Always cucullate	Persistent	200-250
	P. perfoliatus	-	Cordate-amplexicaul	Slightly recurved	Fugacious	-
Ogden (1943)	*P. praelongus*	Often zigzag	Clasping about 1/4 or 2/4	Cucullate	Persistent	200 (-360)
	P. perfoliatus	-	Clasping about 3/4	Noncucullate	Delicate, fugacious	60 (-70)
Haynes (1985)	*P. praelongus*	Zig-zag	Semi-clasping	Cucullate	Persistent	80-280
	P. perfoliatus	-	Clasping	Non-cucullate (flattened)	Stipules delicate	76 (-97)
Kaplan & Wiegleb (1998)	*P. praelongus*	-	Semiamplexicaul	Distinctly hooded	Long, persistent	180 (-360)
	P. perfoliatus	-	Amplexicaul	Slightly hooded	Decaying early	115

As regarding the anatomical differences of the two species, in majority of the previous studies (Raunkier 1903, Hagström 1916) and in our samples, interlacunar bundles and subepidermal bundles are present in *P. praelongus* specimens (Table 3). In *P. perfoliatu*s both interlacunar and subepidermal bundles are either not found or rarely occur in specimens with one or a few small bundles (Raunkier 1903, Wiegleb & Kaplan 1998). Our studies are in parallel to these findings (Figs. 2, 3). Hagström (1916) stated that *P. praelongus* have sclerenchyma cells which we also observed (Fig. 3). In contrast to previous studies (Raunkier 1903, Hagström 1916, Haynes 1985, Wiegleb 1990, Wiegleb & Kaplan 1998), we found trio type stele, not the proto type in *P. praelongus*. Such differences may occur among the populations of very widespread species. Our results showed that steles of our specimens are made up of four median bundles, three of which are united. We found that pseudohypodermis is uniseriate in both species. As a result, it can be stated that the presence interlacunar bundles and sclerenchyma cells are useful anatomical characters to distinguish these two species.

In this study, we present information about the physical and chemical properties of the water where *P. praelongus* and *P. perfoliatus* grow and their other habitat requirements. We give a detailed distribution of the two species based on a broad sampling covering entire Turkey. We also provide new morphological descriptions and the first anatomical studies of the species from Turkey. One of these species, *P. praelongus* is critically endangered (CR) in Turkey and was recorded only from a single site. The other species, *P. perfoliatus* is widespread throughout Turkey occurring under different environmental conditions. As we analyzed the habitat preferences of the species, our study provides useful information for future monitoring of the two species in terms of conservation strategies.

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