An ecological study on the *Isoëtes* community in Istanbul, Turkiye

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Abstract

This study presents phytosociological and some ecological characteristics of the *Isoëtetum durieui* association naturally distributed in Istanbul, Turkiye. During the present study a community was characterised and compared with other communities in different regions of the world. The discussion was followed accordingly. The results obtained from the soil samples of the *I. durieui* association showed that the concentrations of boron, calcium, copper, iron, potassium, magnesium, manganese, lead and zinc were within the limit values, while those of Cd were higher.

Keywords: *Isoëtetum durieui,* ecology, plant sociology, rare species, microphyte

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Introduction

The plant communities are the primary autotrophic components of terrestrial biodiversity. These contribute significantly to the continued sustainability of our biosphere, supporting the overall health, stability and productivity of ecosystems by improving soil fertility, nutrient cycling and water filtration [1-10]. Despite the ecological importance of plant diversity, it is threatened by many factors, including habitat destruction, deforestation, pollution, and climate change, with invasive species at the forefront [10-15]. In order to overcome such threats, studies on the ecological relationships between plant communities and their biotopes are important when studying different ecosystems [15-21].

The genus *Isoëtes* is a globally distributed fern genus [22,23]. Species belonging to the genus *Isoëtes s* are quite small and are known as 'grass ferns' due to their morpho-anatomical similarity to simple grasses [24,25]. Unlike many other fern genera, this genus produces two distinct spores, the species in this genus necessarily show a dependence on water at least at one stage of their development [24]. The fertile, spore-producing parts of the species usually have 2-5 lobes, named "cormus", being located underground. The leaves

show a rosette-like arrangement around the corm. Sporangial sacs at the base of the outer leaves produce macrospores, and sporangial sacs at the base of the innermost and fewer leaves produce microspores. While macrospores have an average diameter of half a millimeter, microspores generally vary in diameter between 10-20 microns [24,26].

The first floristic list for the naturally distributed genus *Isoëtes* in Turkiye was presented by Jermy [27]. Many systematic studies have been undertaken lately and an updated species list of the genus has been published [23-26,28,29]. In Turkiye *Isoëte* genus is represented by 6 species (*I. anatolica* Prada & Rolleri; *I. durieui* Bory; *I. histrix* Bory; *I. olympica* A. Braun; *I. gymnocarpa* (Gennari) A. Braun; and *I. vanensis* M. Keskin & G. Zare). The plant ecological niches are fixed as such, habitat characteristics are very important in their life cycle [30-37]. In view of this, knowing the habitat of a plant community makes it easier to understand its distribution and ecology [3,8-10,15, 21]. The ecological importance of the species from this genus is not well understood due to fragmentary studies. No detailed ecological study has been conducted on the current status of the naturally distributed *Isoëtes* community in Istanbul (Türkiye). Considering this, the present study was carried out to understand the phytosociological and ecological characteristics of *Isoëtes* community.

Table 1: Data on the ecological features covering the quadrats in the *Isoëtes* study area

Quadrat number	Location information	Coordinates	Altitude	Characteristics of the habitat
1	Istanbul Province-Maltepe District: Around Süreyya Pasha Hospital	40.949373 Lat. 29.138577 Lon.	69 m	Degraded grassland near *Pinus pinea* and *P. sylvestris* forest
2	Istanbul Province-Maltepe District: Around Süreyya Pasha Hospital	40.948802 Lat. 29.138196 Lon.	73 m	Degraded grassland near *Pinus pinea* and *P. sylvestris* forest
3	Istanbul Province-Maltepe District: The Süreyya Pasha Hospital - around the pond	40.947184 Lat. 28.146963 Lon.	62 m	Coastal areas of the pond zone
4	Istanbul Province-Maltepe District: Around the village of Büyükbakkal	40.963726 Lat. 29.180356 Lon.	81 m	Meadows close to the road
5	Istanbul Province-Tuzla District: Around the neighborhood of Akfırat	40.950375 Lat. 29.412182 Lon.	152 m	Meadows along the road in the area around the Formula 1 race track
6	Istanbul Province-Tuzla District: Around the neighborhood of Akfırat, Around the Formula 1 racing area	40.950375 Lat. 29.412182 Lon.	155 m	Large grasslands opposite the Formula 1 race track

Materials and Methods

Study area

The commanding feature of Istanbul is that it is located on two continents (Europe and Asia), between two seas (Marmara and Black Sea) and in two phytogeographical regions (Euro-Siberian and Mediterranean) [15]. The climate is a typical four-season continental Mediterranean climate with warm summers (above 30 ^{o}C) and mild winters (rarely below 0 ^{o}C). The average temperature is 14.1 ^{o}C and the average rainfall is 820 mm [15]. It is part of the Euro-Siberian region represented by the Euxine sub-region, while the Mediterranean region belongs to the East Mediterranean province [15,38-40]. This position is reflected in the great diversity of flora and vegetation in Istanbul [15].

Floristic data

The floristic composition of the *Isoëtes* community has been done recently by Keskin et al. [41]. For the identification of *Isoëtes* species and other fern species, the studies of Bolin et al. [23], Keskin and Musselman [24], Keskin [25,42] and Keskin et al. [43] were considered. The species identification was done for the moss species following the studies of Spence and Ramsay [44], Elharech et al. [45], Ozturk et al. [46] and Sjölander [47].

Ecological data

Ecological data was collected using the random homogeneous square sampling method. Each sample area was taken as 1 m^2 and a total of 6 quadrats were taken in the study area. (Table 1). All plants in each quadrat were recorded. The Braun-Blanquet approach [48] was used to classify the floristic composition found in each quadrat in terms of plant sociology. For syntaxonomic nomenclature and synonyms of higher levels of classification, Brullo et al. [49] was followed, in the light of most recent data.

Soil analysis

After drying for 48 hours at 80 °C, soil samples are sieved through a 2 mm steel mesh to obtain a uniform particle size distribution suitable for subsequent analysis. Samples weighing 0.200-0.250 g were transferred to Teflon containers for further processing. For soil samples, a solution containing 6 ml of 65 percent Merck's HNO_3, 3 ml of 37 percent Merck's HCl and 2 ml of 48 percent HF was prepared and added to the vessels. The samples were subjected to a dissolution process using a Berghof-MSW2 microwave apparatus to optimise efficiency and precision. At the end of dissolution, the samples were filtered through Whatman blue-banded filter paper into sterile 50 ml Falcon tubes using ultrapure water, total volume of the filtrate was adjusted to 50 ml to ensure uniformity and consistency in subsequent analyses. The samples prepared as such were used to determine elemental concentrations using inductively coupled plasma optical emission spectroscopy (ICP-OES), a PerkinElmer - Optima 7000DV instrument. The contents of B, Ca, Cd, Cu, Fe, K, Mg, Mn, Pb and Zn, expressed in mg/kg dry weight were determined [12, 36,37,50,51].

Results and Discussion

Looking at the floristic composition of the *Isoëtetum durieui* association distributed in the study area, we recorded that it develops in early spring and is characterised by the dominance of *Juncus capitatus* and *Isoëtes durieui*, growing together with hygrophilous microphytes (Table 2). The association is also characterized by pioneer ephemeral vegetation. Considering the structure and ecology of the association in terms of plant sociology, it is compatible with the

characteristic species of the Isoëto-Nanojuncetea class, Isoëtalia order and Isoëtion alliance [49]. In all the quadrats of the *Isoëtetum durieui* association identified by us, the moss species *Ptychostomum pseudotriquetrum*, had high ecological tolerance, and *Ophioglossum lusitanicum* fern-a microphyte, always accompanied this association. A similar report has been recorded by other researchers [24, 42, 52].

The syntaxonomic structure of the *Isoëtetum durieui* association is given below:

Class: Isoëto-Nanojuncetea Br.-Bl. & R. Tx. ex Westhoff, Dijk & Passchier 1946
Order: Isoëtetalia Br.-Bl. 1936 nom. conserv. propos.
Alliance: Isoëtion Br.-Bl. 1936
Association: *Isoëtetum durieui* Br.-Bl. 1936 (Table 2).

This plant association was first introduced to the scientific world by Braun-Blanquet [53] in the south of France. The phytosociological studies carried out by various researchers in subsequent year have shown that the association is

Table 2: *Isoëtetum durieui* association in the study area

Quadrate number	1	2	3	4	5	6
Altitude (m)	69	73	62	81	152	155
Quadrate samples width (m^2)	1	1	1	1	1	1
Direction (^{0})	E	SE	E	E	-	SE
Slope (%)	5	15	20	30	5	5
Plant cover (%)	60	95	75	90	95	85
Isoëtes durieui	33	44	33	33	44	33
Juncus capitatus	12	12	12	12	12	12
***Isoeto-Nanojuncetea* Class**						
Juncus hybridus	+2	+2	+1	+1	+2	+1
Poa infirma	+1	-	+2	+2	+2	+2
***Isoetion* Alliance and *Isoetalia* Order**						
Isoëtes histrix	12	12	+2	12	+2	+2
Lotus conimbricensis	+1	+1	+1	+1	+1	+1
Companions						
Ptychostomum pseudotriquetrum	22	33	12	12	12	12
Ophioglossum lusitanicum	+2	+2	+1	+2	+1	+2
Sagina apetala	+2	-	+2	+2	+2	+2
Plantago coronopus	12	-	12	11	-	12
Calendula arvensis	12	12	11	11	-	-
Ornithogalum sigmoideum	12	-	11	12	11	-
Plantago lanceolata	-	12	-	-	12	12
Erodium cicutarium	-	-	11	12	+1	-
Poa bulbosa	+1	-	-	-	-	+1
Hypericum triquetrifolium	-	+1	+1	-	-	-
Sedum hispanicum	-	11	-	12	-	-
Montia minor	-	-	-	+2	+2	-
Polygonum istanbulicum	11	-	-	-	-	-
Prospera autumnalis	+1	-	-	-	-	-
Euphorbia helioscopia	+1	-	-	-	-	-
Cynodon dactylon	-	-	-	-	+2	-
Lotus corniculatus	-	-	-	-	-	+2

widespread in the south of France, in Catalonia and Corse in Spain, and in Italy (particularly in Sicily) [49,54-62].

In contrast to the *Isoëtetum durieui* association, another study has been reported on the occurrence of *Isoëtes histrix* community in Turkiye [63]. Regarding the habitat preferences of this community, it has been reported that it has a limited distribution in acidophytic, seasonally dry and winter submerged areas in the Mediterranean zone of the Menderes massif in the western part of Turkiye [63].

The association found in our study area varies in terms of ecological preferences being generally distributed at an altitude of 62-155 m, on slopes verying between 5-30 percent of the land facing south and southeast.

In the light of its habitat preferences, *I. durieui* community is generally found in small depressions on land, along the banks intermittent streams and in other areas where water is available for most of the year, if not during the summer [64]. All terrestrial *Isoëtes* species distributed in Turkiye are similar in their habitat preferences. These species are prominent habitat types in small green areas in pine forest clearings, open and wide meadows, small seasonal water bodies, around volcanic rocks and paths formed by water currents in meadows [25]. It was determined that *I. durieui* association distributed in the study area had similar habitat preferences.

The elemental concentrations present in the soil samples were in the following decreasing order K > Fe > Ca > Mg > Mn > Zn > Cu > B > Pb > Cd. We can say that K values are the highest while Cd values are the lowest. The values of K, Fe, Ca, Mg, Mn, Zn, Cu, B and Pb are within the limits, but those of Cd are above the limits (Table 3). According to the elemental

Table 3: Elemental analysis (mg kg^{-1}) in the soil samples of *Isoëtetum durieui* and limit values (mg kg^{-1}) of analyzed elements

	Locality 1	**Locality 2**	**Locality 3**	**Locality 4**	**Locality 5**	**Locality 6**	**Limit values [66-68]**
B	26,475±0,527	26,835±0,516	25,596±0,501	24,655±0,470	25,949±0,493	27,045±0,554	20-200
Ca	3176,381±58,649	3214,9±59,356	3061,034±56,503	2945,107±54,405	3098,66±57,193	3136,267±57,893	7000-15000
Cd	2,814±0,095	2,896±0,082	2,783±0,077	2,682±0,098	2,832±0,074	2,877±0,102	0.06-1.1
Cu	29,344±0,554	29,744±0,595	28,362±0,526	27,333±0,508	28,788±0,558	29,157±0,595	25-75
Fe	3814,286±70,427	3860,567±71,265	3675,758±67,829	3536,558±65,278	3720,945±68,692	3766,083±69,519	5000-50000
K	4976,371±91,882	5036,752±92,989	4795,625±88,492	4614,01±85,155	4854,551±89,617	4913,459±90,697	5000-25000
Mg	2105,577±38,858	2131,112±39,335	2029,09±37,460	1952,278±36,049	2054,042±37,958	2078,988±38,376	300-8400
Mn	106,769±2,011	108,084±2,051	102,953±1,914	99,054±1,883	104,234±1,980	105,498±1,96	10-9000
Pb	11,991±0,232	12,159±0,236	11,595±0,259	11,172±0,233	11,768±0,218	11,959±0,252	10-40
Zn	72,308±1,370	73,216±1,386	69,72±1,331	67,125±1,282	70,658±1,337	71,519±1,325	3-300

analysis results of the soil samples, the study area shows potential contamination in terms of Cd, which is readily absorbed by plants, having toxic effects, potentially inhibiting plant growth and metabolic functions, especially in aquatic and terrestrial ecosystems [65].

Among macrophytes, *Isoëtes s* species are particularly sensitive and are distributed in very limited geographical areas. The plants of this genus are seriously threatened [69]. The factors contributing to the decline and/or extinction of *Isoëtes* species include habitat degradation or loss, pollution, competitive exclusion by related plants, and intense disturbance due to anthropogenic impacts [36,51,70].

Isoëtes species are included within a spore-bearing group of plants, requiring water in the life cycle, especially to reach their ripening stage. As a result of climate change and drought, the distribution of these plants is narrowing. In addition, locally observed anomalies in seasonal rainfall put ecological pressures on their populations. In addition to tense pressures these plants must also struggle with the invasive species. *Isoëtes* generally prefers sunny and open grasslands due to their ecological requirements. They are unable to compete in these habitats due to pressure from invasive flowering plants that are taller, and intense anthropogenic impacts, especially activities such as construction and road building, disrupt the ecological adaptation of sensitive *Isoëtes* species.

Conclusion

Understanding *Isoëtes* species and their habitats from an ecological and synecological perspective on a global scale will contribute to their conservation. The results presented here include ecological findings on the *Isoëtetum durieui* association distributed in Istanbul (Turkiye). This study partially contributes to the elucidation of the ecological requirements, floristic composition and phytosociological structure of the *Isoëtetum durieui* association. Moreover, as with endemic, relict and rare plants, these species need more detailed ecological, eco-physiological and molecular studies to reveal the eco-genetic diversity of *Isoëtes* species [36,51].

References

1. Austin M.P. The potential contribution of vegetation ecology to biodiversity research: Ecography. 1999;22(5):465-84.
2. Altay V, Keskin M, Karahan F. An assessment of the plant biodiversity of Mustafa Kemal University Tayfur Sokmen Campus (Hatay-Turkey) for the view of human health: Int J Sci Technol Res. 2015;1(2):83-103.
3. Egamberdieva D, Ozturk M. Vegetation of Central Asia and Environs. Springer Nature; 2018.
4. Eisenhauer N, Hines J, Isbell F, van der Plas F, Hobbie SE, Kazanski CE, Lehmann A, Liu M, Lochner A, Rillig MC, Vogel A, Worm K, Reich P.B. Plant diversity maintains multiple soil functions in future environments. eLife. 2018; 7:e41228.
5. Ozturk M, Secmen O, Gork G. Plant Life in Southwest and Central Asia. Vol. I, Ege Univ. Press Izmir, Turkiye; 1996a.
6. Ozturk M, Secmen O, Gork G. Plant Life in Southwest and Central Asia. Vol. II. Ege Univ. Press Izmir, Turkiye; 1996b.
7. Ozturk M, Altay V, Gucel S, Aksoy A. Aegean grasslands as endangered ecosystems in Turkey: Pak J Bot. 2012; 44:7-18.
8. Ozturk M, Altay V, Efe R. Biodiversity of West Asia-Caucasus: Prospects and Challenges for Conservation and Sustainable Use Vol. I., Springer Nature; 2021b.
9. Ozturk M, Khan SM, Altay V, Efe R,

Egamberdieva D, Khassanov F. Biodiversity, Conservation and Sustainability in Asia. Vol. II. Prospects and Challenges in South and Middle Asia. Springer Nature; 2022.
10. Altay V. Ecology of *Pinus sylvestris* L. forests–a case study from Istanbul (Turkey). Pak J Bot. 2019; 51(5):1711-18.
11. Ozturk M, Mermut A, Celik A. Land Degradation, Urbanisation, Land Use & Environment. NAM S. & T., Delhi-India; 2011.
12. Ozturk M, Altay V, Kucuk M, Yalçın I.E. Trace elements in the soil-plant systems of copper mine areas - A case study from Murgul Copper Mine from the Black Sea Region of Turkiye. Phyton-Inter. J. Experi. Bot. 2019; 88:223-38.
13. Imanberdieva N, Severoğlu Z, Kurmanbekova G, Altay V, Ozturk M. Plant diversity of Ala-Archa National Park in Kyrgyzstan with emphasis on its economical potential. Vegetation of Central Asia and environs. Springer Nature; 2018a. p. 365-381.
14. Imanberdieva N, Imankul B, Severoğlu Z, Altay V, Ozturk M. Potential impacts of climate change on plant diversity of Sary-Chelek Biosphere Reserve in Kyrgyzstan. Vegetation of Central Asia and environs. Springer Nature; 2018b. p. 349-364.
15. Altay V, Šilc U, Yarcı C, Kavgacı A, Čarni A, Ozturk M. Urban vegetation of the Anatolian side of Istanbul. Phytocoenologia. 2020; 50(2), 101.
16. Altay V, Ozturk M. Land degradation and halophytic plant diversity of Milleyha wetland ecosystem (Samandağ-Hatay), Turkey. Pak J Bot. 2012; 44:37-50.
17. Altay V, Ozyigıt II, Yarcı C. Plant communities in urban habitats of Istanbul-Turkey. Pak J Bot. 2012; 44, 177-86.
18. Ozyigit S, Altay V, Ozyigit II, Yarci C. Vegetation ecology of the Princes' Islands, Istanbul-Turkey. Journal of Environmental Biology. 2015; 36(1):113.
19. Sezer Y, Altay V, Ozyıgıt II, Yarcı C. Woody vegetation of Şile and its environs (Istanbul/Turkey) and destruction of the area. J Environ Biol. 2015; 36:163-70.
20. Corlett, R.T. Plant diversity in a changing world: Status, trends, and conservation needs. Plant Diversity. 2016; 38(1): 10-6.
21. Ozturk M, Altay V, Yarcı C, Yücel E, Kutbay HG (2021a). Endangered Swamp Forests in Turkey-An Ecological Inventory, Prospects, and Challenges. In: Biodiversity, Conservation and Sustainability in Asia: Volume 1: Prospects and Challenges in West Asia and Caucasus. Springer; 2021a. p. 61-79.
22. Motelay L, Vendryes A. Monographie des *Isoetaceae*. Act. Linn. Bordeaux. 1884; 36:309-403.
23. Bolin JF, Bray RD, Keskin M, Musselman L.J. The Genus *Isoëtes* L. (Isoetaceae, Lycophyta) in South-Western Asia. Turk. J. Bot. 2008; 32:447-57.
24. Keskin M, Musselman L.J. Türkiye'nin Çimeğreltisi [*Isoëtes* L. (Isoetaceae)] türleri. Bağbahçe Bilim Dergisi. 2014; 1(2):1-13.
25. Keskin M. *Isoëtes* L. In: Güner, A. et al. (eds), Resimli Türkiye Florası cilt 2: 99-110, İstanbul; 2018a.
26. Prada C, Rolleri C.H. A new species of *Isoëtes* (Isoetaceae) from Turkey, with a study of microphyll intercellular pectic protuberances and their potential taxonomic value. Bot. J. Linn. Soc. 2005; 147:213-28.
27. Jermy A.C. *Isoëtes* L. In: Davis, P.H., Mill, R.R. and Tan, K. (eds), Flora of Turkey and The East Eagean Islands, Vol. 1, Edinburgh University Press, Edinburgh; 1965. p. 36-38.
28. Keskin, M. *Isoëtes*. In Güner, A. et al. (eds.), Türkiye Bitkileri Listesi (Damarlı Bitkiler). Nezahat Gökyiğit

Bahçesi ve Flora Araştırmaları Derneği Yayını. İstanbul; 2012.
29. Zare G, Keskin M, Doğru-Koca A, Armağan M. *Isoëtes vanensis* (Isoëtaceae) sp. nov. from Turkey. Phytotaxa. 2016; 269(4):294-300.
30. Eskin B, Ozyiğit II, Doğan I, Altay V, Demir G, Serin M. Germination physiology and autecology of *Centaurea kilaea* Boiss. from Turkey. Sains Malaysiana. 2013; 42(10):1473-82.
31. Eroglu HK, Ozyigit II, Altay V, Yarcı C. Autecological characteristics of *Centaurea hermannii* F. Herm.: An endemic species from Turkey. Bulgarian Journal of Agricultural Science. 2014; 20(1):183-87.
32. Altay V, Ozyigit II, Keskin M, Demir G, Yalçın I.E. An ecological study of endemic plant *Polygonum istanbulicum* Keskin and its environs. Pak J Bot. 2013; 45(S1):455-9.
33. Altay V, Karahan F, Ozturk M, Hakeem KR, Ilhan E, Erayman M. Molecular and ecological investigations on the wild populations of *Glycyrrhiza* L. taxa distributed in the East Mediterranean Area of Turkey. Journal of Plant Research. 2016a; 129(6):1021-32.
34. Altay V, Gulyanar S, Ozyigit I.I. Autecology of *Cephalaria taurica* Szabó, a narrow endemic from Turkey: Plant-soil interactions. IOSR Journal of Environmental Science, Toxicology and Food Technology. 2016b; 10(9):90-4.
35. Altay V, Daloglu MY, Ozturk M. Edaphic relations of *Cirsium cassium* Davis & Parris (Asteraceae), a local endemic from Hatay (Turkiye). Anatolian Journal of Botany. 2017; 1(2):41-4.
36. Altay V, Celik O, Ozturk M. An investigation on plant-soil interactions in some endemic *Centaurea* taxa from Hatay, Turkiye. International Journal of Applied and Experimental Biology. 2024; 3(1):31-6.
37. Ozturk M, Altay V, Kucuk M, Altundağ E, Severoğlu Z, Yalçın I.E. Preservation and ecology of a living relict shrub in South Caucasus as a eco-genetic heritage from Tertiary: *Epigaea gaultherioides* (Boiss. & Bal.) Takht. Journal of Environmental Biology. 2020; 41(SI):279-84.
38. Eskin B, Altay V, Ozyıgıt II, Serin M. Urban vascular flora and ecologic characteristics of the Pendik District (Istanbul-Turkey). African Journal of Agricultural Research. 2012; 7(4):629-46.
39. Altay V, Ozyıgıt II, Yarci C. Urban flora and ecological characteristics of the Kartal District (Istanbul): a contribution to urban ecology in Turkey. Scientific Research and Essays. 2010; 5(2):183-200.
40. Altay V, Ozyigit II, Osma E, Bakir Y, Demir G, Severoglu Z, Yarci C. Environmental relationships of the vascular flora alongside the railway tracks between Haydarpaşa and Gebze (Istanbul-Kocaeli/Turkey). J Environ Biol. 2015b; 36(1):153-62.
41. Keskin M, Altay V, Ozturk M. Traditional Use of Plant Diversity for Nutritional Purposes: A Case Study from Istanbul (Turkiye). In: Ethnic Knowledge and Perspectives of Medicinal Plants. Apple Academic Press; 2024. p. 3-56.
42. Keskin M. *Ophioglossum* L. In: Güner, A. et al. (eds.), Resimli Türkiye Florası 2: 130-133. ANG Vakfı Nezahat Gökyiğit Botanik Bahçesi Yayınları. İstanbul; 2018b.
43. Keskin M, Altay V, Ozturk M. (2023). Evaluation of Medicinal and Ecological Aspects of Pteridophytes in Turkiye. In Plants as Medicine and Aromatics. CRC Press; 2023. p. 309-324.
44. Spence JR, Ramsay H.P. Australian Mosses Online. 50. Bryaceae: *Ptychostomum*; 2012. Available from http://www.anbg.gov.au/abrs/Mosses_online/Bryaceae_Ptychostomum.pdf.

45. Elharech M, Belahbib N, Achoual K, Magri N, Dahmani J. Bryophytic diversity of Bouknadel's Exotic Gardens (Morocco): New Species. Biolife. 2018; 6(1):28-36.
46. Ozturk M, Gökler I, Altay V. (Medicinal bryophytes distributed in Turkey. Plant and Human Health, Volume 1: Ethnobotany and Physiology. Springer Nature; 2018. p. 323-348.
47. Sjölander I. A comparative study of the mosses *Ptychostomum pseudotriquetrum* and *P. bimum*: Investigating morphological characters, habitat, and distribution across northern Sweden. [Bachelor thesis], Umea Universitet; 2022.
48. Braun-Blanquet J. Plant Sociology: The Study of Plant Communities (English translation). McGraw-Hill, New York; 1932.
49. Brullo S, Brullo C, Sciandrello S, Tavilla G, Cambria S, Tomaselli V, ... Minissale P. The plant communities of the class Isoëto-Nanojuncetea in Sicily. Plants. 2022; 11(9):1214.
50. Ozyigit II, Dogan I, Eskin B, Keskin M, Demir G, Yalcin I.E. (2013). Mineral element uptake status of endemic *Isoëtes anatolica* Prada & Rolleri populations from Bolu-Turkey. Pak. J. Bot. 2013; 45(S1):515-19.
51. Ozturk M, Altay V, Gul A, Altundag E, Kucuk M. (2024). An ecological study on *Betula medwediewii* Regel and *Veratrum album* L. naturally distributed in the subalpine region of West Transcaucasia. Plant & Fungal Research. 2024; June:11-16.
52. Poponessi S, Aleffi M, Gigante D, Venanzoni R. Updates on the bryophyte flora of the lowland woods and temporary ponds west of Lake Trasimeno (Central Italy). Flora Mediterranea. 2016; 26:151-62.
53. Braun-Blanquet J. Un joyau fioristique et phytosociologique "L'Isoetion» méditerranéen. Bull. Soc. Etude Sci. Nat. Nimes 1936; 47:141-63.
54. Moor M. Ordung der Isoetetalia. Prodr. Group. Vég. 1937; 4:1-24.
55. De Bolòs A, de Bolòs O. La Vegetación de las Comarcas Barcelonesas. Instituto Español de Estudios Mediterráneos: Barcelona, Spain; 1950. p. 8-579.
56. Braun-Blanquet J, Roussine N, Nègre R. Les Groupements Végétaux de la Franee Méditerranéenne. C.N.R.S.: Paris, France; 1952. p. 1-297.
57. Molinier R. Etude des groupements vegetaux terrestres du Cap Corse. Bull. Mus. Hist. Nat. Marseille. 1959; 19:1-75.
58. De Bolòs O. Comunidades vegetales de las comarcas próximas al litoral situadas entre los ríos Llobregat i Segura. Mem. R. Acad. Cienc. Art. Barc. 1967; 38:1-269.
59. Marcenò C, Trapani S. L'Isöetetum duriaei (*Isöetion*) nella Piana dei Greci (Sicilia occidentale). Atti Acc. Sc. Lett. Arti Palermo. 1978; 35:395-9.
60. Ballesteros E. Sobre l'estructura i la dinàmica de les comunitats terofítiques humides (classe Isoeto-Nanojuncetea) i els pradells amb *Ophioglossum lusitanicum* L. del massís de Cadiretes (la Selva). Collect. Bot. Barc. 1984; 15:39-57.
61. Franquesa T. El paisatge vegetal de la península del cap de Creus. Arx. Sec. Cièn. 1995; 109:1-628.
62. Ninot JM, Carreras J, Carrillo E, Vigo J. Syntaxonomic conspectus of the vegetation of Catalonia and Andorra. I: Hygrophilous herbaceous communities. Acta Bot. Barc. 2000; 46:191-237.
63. Kürschner H, Parolly G. On the occurrence of *Isoëtes histrix* in the Menderes Massif of western Turkey - a synecological study and the first record of an *Isoëtion* community for Turkey. Bot Jahrb Syst. 1999; 121:423-51.
64. Molina J.A. The vegetation of temporary ponds with *Isoëtes* Phytocoenologia. 2005; 35(2-3):219-30.

65. Ghori NH, Ghori T, Hayat MQ, Imadi SR, Gul A, Altay V, Ozturk M. Heavy metal stress and responses in plants. Intern. Journal of Environmental Science and Technology. 2019; 16:1807-28.
66. Kabata-Pendias A, Pendias H. Trace Elements in Soils and Plants. 3rd ed. CRC Press: Boca Raton, New York, Washington, D.C.; 2001.
67. Barker AV, Pilbeam D.J. Handbook of Plant Nutrition. CRC Press; 2015.
68. Yalcin IE, Altay V. Investigation of water-soil-plant relationships based on hazardous and macro-micro element concentrations on Orontes River, Türkiye. International Journal of Phytoremediation. 2023; 25(14):1859-80.
69. Bolpagni R, Magrini S, Coppi A, Troìa A, Alahuhta J, Mjelde M, Azzella M.M. *Isoëtes sabatina* (Isoëtaceae, Lycopodiopsida): Taxonomic distinctness and preliminary ecological insights. Aquatic Conservation: Marine and Freshwater Ecosystems. 2021; 31(10):2690-6.
70. Liu X, Wang JY, Wang Q.F. Current status and conservation strategies for *Isoëtes* in China: a case study for the conservation of threatened aquatic plants. Oryx. 2005; 39(3):335-8.