

Updating the distribution of the genus *Isoetes* (Isoetaceae) in southern Spain (Córdoba, Andalusia)

Actualización de la distribución del género *Isoetes* (Isoetaceae) en el sur de España (Córdoba, Andalucía)

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ABSTRACT

Isoetes belong to the Class Lycopodiopsida (lycophytes). The genus is generally underrepresented in collections due to a lack of diagnostic characteristics and inconspicuous appearance. The current distribution of *Isoetes* within Córdoba province is provided in a 1 km² grid from several sources: (i) herbaria sheets from COA, COFC, MGC, SEV, GDA, and GDAC, (ii) 107 new observations since 2012, and (iii) records from literature and databases. Nine herbaria sheets were correctly determined. The most frequent species was *I. histrix*, well represented in the northern half of the province. *Isoetes duriei*, *I. longissima*, and *I. delilei* were much less common. The present work aims to update the current distribution of this genus in Córdoba province (Spain), in which several species are classified as threatened.

Keywords. Andalusia, Córdoba, Lycopodiopsida, Spain.

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RESUMEN

El género *Isoetes* pertenece a la clase Lycopodiopsida (Licófitos). El género está generalmente poco representado en colecciones debido a la falta de caracteres diagnósticos y a ser poco conspicuo. La distribución actual de las especies del género *Isoetes* en la provincia de Córdoba se proporciona en una resolución de 1 km² a partir de varias fuentes: (i) pliegos de los herbarios COA, COFC, MGC, SEV, GDA y GDAC; (ii) 107 nuevas observaciones llevadas a cabo desde el año 2012, y (iii) consulta de publicaciones y bases de datos. Nueve pliegos de herbario han sido correctamente identificados. La especie más frecuente es *I. histrix*, que se presupone bien representada en la mitad norte de la provincia. *Isoetes duriei*, *I. longissima* e *I. delilei*, son menos comunes. Con el presente trabajo se actualiza la distribución de este género en la provincia de Córdoba (España), donde algunas de sus especies están catalogadas como amenazadas.

Palabras clave. Andalucía, Córdoba, España, Lycopodiopsida.

INTRODUCTION

Isoetes is a genus that belongs to Class Lycopodiopsida (Schuettpelz *et al.* 2016), being the only living genus from the Isoetaceae (Jermy 1990). Its diversity is over 200 species (Troia *et al.* 2016) distributed around the world excepting Antarctica (Troia and Greuter 2015). They are perennial herbs, aquatic, amphibious or terrestrial, with short stems similar to bulbs usually underground. Sporophylls linear, ligulate, subulate, spirally arranged, broader at the base, the ala, with sporangia solitary, sessile, naked, or covered by a total or a partial velum, heterosporous, numerous roots dichotomously branched. Some species may have stiff and blackish leaf remnants called phyllopods (Prada 1986, Jermy and Akeroyd 1993).

In the Andalusia region (southern Spain) four species are present: *I. histrix* Bory (*sensu lato*), *I. duriei* Bory, *I. longissima* Bory and *I. delilei* Rothm. The latter three are assessed as threatened by the regional government. *Isoetes duriei* and *I. delilei* (sub. *I. setacea* Lam.) are considered as vulnerable (VU) by Ley 8/2003, de 28 de octubre, de la Flora y la Fauna Silvestres of the Andalusia government and by Cabezudo and Talavera (2005). *Isoetes longissima* (sub. *I. velata* A. Braun subsp. *velata*) is catalogued as data deficient (DD) (Cabezudo and Talavera 2005). More recently, Decreto 23/2012, de 14 de febrero, por el que se

regula la conservación y el uso sostenible de la flora y la fauna silvestres y sus hábitats includes *I. delilei* within the Listado Andaluz de Especies Silvestres en Régimen de Protección. In the same decree, *I. duriei* is incorporated in Catálogo Andaluz de Especies Amenazadas still as vulnerable. *Isoetes histrix* appeared as not threatened and it is the most widespread in Andalusia, although it is not occurring in Granada province. By contrast, the other species are less common. *Isoetes duriei* grows in Cádiz, Córdoba, Huelva, Jaén and Málaga; *I. longissima* grows in Cádiz, Córdoba, Granada, Huelva and Sevilla and *I. delilei* grows in Córdoba, Huelva and Sevilla (Cabezudo and Salvo 1987, Pérez-García *et al.* 2005, Delgado Vázquez and Plaza Arregui 2010, Cabezudo 2011, López Tirado *et al.* 2015, López Tirado 2018). *Isoetes histrix* and *I. duriei* are terrestrial plants with phyllopods and occasionally found together in the same habitat. By contrast, *I. longissima* and *I. delilei* are amphibious species without phyllopods and required a flooding period. Only Córdoba and Huelva provinces (western Andalusia) have the four species here mentioned. In fact, the preference of these species for siliceous soils and acid rocks determines the distribution along Andalusia, resulting rarer in eastern Andalusia where limestone substrates prevail. This work aims to update the distribution of the genus *Isoetes* in Córdoba province from southern Spain by revision of herbaria sheets, active field observations since 2012, and records from literature and databases.

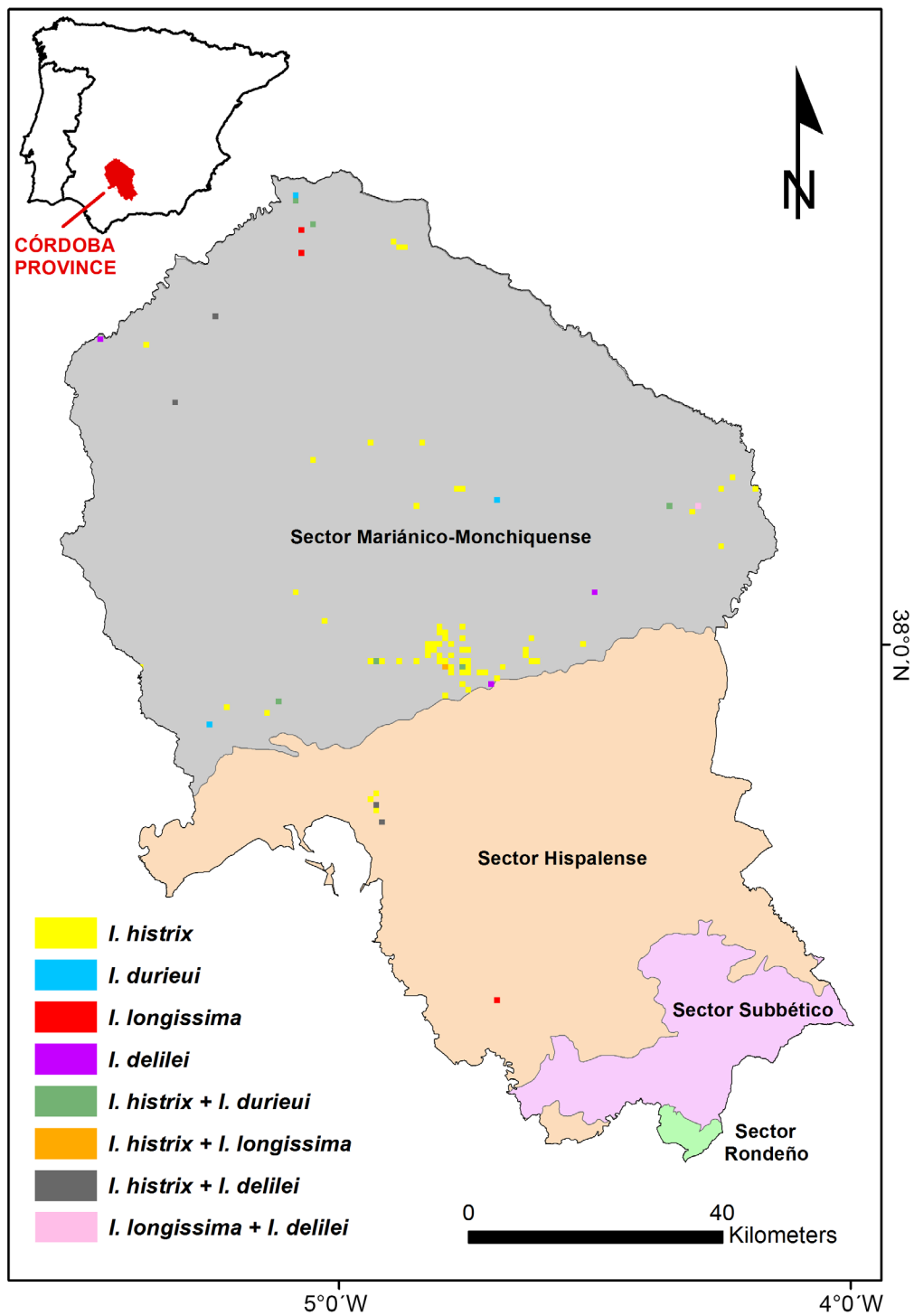


Figure 1. Location of Córdoba province within the Iberian Peninsula, biogeographic sectors and distribution of *Isoetes* species.

MATERIAL AND METHODS

The distributional data for *Isoetes* concerning Córdoba province was gathered considering: (i) deposited specimens from COFC (*Herbario de la Facultad de Ciencias de la Universidad de Córdoba*), COA (*Herbario del Real Jardín Botánico de Córdoba*), MGC (*Herbario de la Facultad de Ciencias de la Universidad de Málaga*), SEV (*Herbario de la Universidad de Sevilla*) and GDA-GDAC (*Herbario de la Universidad de Granada*) (see [Appendix](#)), (ii) specimen surveying by the author since 2012, and (iii) chorological records from literature and databases such as www.anthos.es and www.gbif.es.

Herbaria sheets were revised as follows: COFC (January 8th 2019), COA (May 13th 2020), MGC (September 7th 2020), SEV (September 18th 2020) and GDA-GDAC (December 17th 2020). The main characters to correctly identify the species which occur in Córdoba province were related to megaspores, i.e. shape, size and especially surface ornamentation following Prada (1986). Phyllospores (leaf base) and habitat of the specimens were of interest when personally observed.

GPS coordinates of directly observed specimens were collected with a GPS Garmin Etrex 30. The observation period was carried out during the whole year, excluding summer season because at this time *Isoetes* usually lose the aerial portion of the plant. This information, together with herbaria sheets, led to a 1 km² distribution map using ArcMap 10.4.1 software (ESRI 2016).

RESULTS

Field work since 2012 found 107 new localities. A total of 68 herbaria sheets were revised from herbaria located in Córdoba and surrounding provinces. Some of these herbaria sheets matched with records from databases. In total, 175 records were retrieved. The most observed species was *I. histrix*. There were more herbaria sheets of *I. delilei* than *I. durieui* and *I. longissima* because specimens were actively collected in different periods from the same locality (see [Appendix](#)). Nine out of 68 herbaria sheets were misidentified or lack the specific epithet. Correctly applied scientific name was given to seven out of nine herbaria sheets whereas the remaining two collections did not belong to *Isoetes*.

Isoetes histrix was present in 77 grids, *I. durieui* did it in nine, *I. longissima* in five and finally *I. delilei* in eight ([Fig. 1](#)).

DISCUSSION

Córdoba province is located in southern Spain, in the Andalusia region. It is an inland territory that, biogeographically, can be divided into two halves separated by the Guadalquivir River. The northern half belongs to Provincia Mediterránea Ibérica Occidental (Subprovincia Luso-Extremadurensis, Sector Mariánico-Monchiquense). This area is a central sector of Sierra Morena range; mainly characterized by acid soils and rocks with quartzites, schists, and granites among other minerals although limestones outcrops can be found. The southern half mainly belongs to Provincia Bética (Sector Hispalense) ([Fig. 1](#)) (Rivas-Martínez 2005). It is made up of marls and limestones; the highest point of the province (1570 m) is found in the south within Sector Subbético. From this point of view, *Isoetes* species distribution is biased based on their ecological requirements. They generally grow in acid surfaces; therefore, the southern half of the province is not suitable excepting moist and sandy areas. In contrast, the northern half is mostly adequate habitat for this genus. All the species need moist or flooding zones; *I. histrix* can be found in less humid pasturelands nonetheless. In moister places it can be found together with *I. durieui* like in stream riverbanks (López Tirado *et al.* 2015). *Isoetes histrix* is also present in some of the grids of *I. longissima* and *I. delilei*. In this case, *I. histrix* do not share the same habitat, as always is found outside of flooded areas.

The higher abundance of *I. histrix* in the centre of the province ([Fig. 1](#)) is explained by a greater sampling in the surroundings of Córdoba town. This result can be of interest to understand the commonness of this species, which could be also found in most of the northern half grids. By contrast, Triano (2010) excludes *I. histrix* from sector Subbético. Thus, its distribution in the southern half must be reduced to some grids of Guadalquivir municipality. Scattered and scarce localities of *I. durieui* were found. After almost a decade collecting *Isoetes*, it is clear that *I. durieui* is much less common than *I. histrix* (100 samples of *I. histrix* in opposition to three of *I. durieui*). Findings in other territories like Huelva province and Central Italy suggest the preference of *I. durieui* to rainier areas (López Tirado *et al.* 2015, López Tirado and Scoppola 2016). *Isoetes longissima* and *I. delilei* are restricted to annually flooded areas. They prefer shallow ponds in sandy soils and also being found more rarely in stream beds. Suitable areas in the southern half of Córdoba province are an

exception, such as *I. longissima* in Puente Genil municipality (Devesa *et al.* 2018) and *I. delilei* in Guadalquivir municipality (López Tirado *et al.* 2016). By contrast, the northern half is better preserved and more suitable for these amphibious species.

Surface ornamentation of the megaspores was the main character to consider when identifying (Prada 1983), especially distinguishing between terrestrial species. Other traits like presence/absence of phylloids or velum and habitat can also be significant. Nonetheless, phylloids' presence without considering megaspores seems to be the common mistake to a wrong identification.

Isoetes specimens have not been traditionally and steadily collected, probably because they go unnoticed. This work updates the distribution of this genus in Córdoba province. It highlights the commonness of *I. hixtrix*, especially in comparison with the other terrestrial species *I. durieui*. Both of them cannot be correctly identified unless mature megaspores are checked. A total of 107 new localities provided by the author after a decade of sampling are recorded for three out of four threatened species. These new localities have been collected and they are still saved by the author for further analysis.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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APPENDIX

ISOETES HISTRIX: Alcaracejos: Ctra. de Alcaracejos, en intersección con el arroyo Fresnedoso, antes de la desviación a Pozoblanco, 23-IV-1984, *F. Infante and J.M. Muñoz s.n.* (COFC 53243). El Viso: Arroyo del Romano, 12-II-1997, *J. Garrido and C. Olivares s.n.* (COFC 25432-3). Córdoba: tramo alto del arroyo de Linares, 530 m, 10-IV-2011, *J. López Tirado and E. Ruiz de Clavijo* (COFC 60756). Posadas: cortijo Las Platas, 02-IV-1997, *R. Martínez and A. Ortiz s.n.* (COFC 25534-1). Córdoba: Río Guadiato, margen derecha, entre el puente de la ctra. de Villaviciosa de Córdoba y el arroyo Bejarano, 04-V-1978, *E. Ruiz de Clavijo and J. A. Varela* (COFC 1688). El Viso: Arroyo del Romano, 12-II-1997, *J. Garrido and C. Olivares s.n.* (COFC 25531). Hornachuelos: Sierra de Hornachuelos, Parque Natural, finca Rincón Bajo, 17-III-1997, Leg.: *R. Martínez and A. Ortiz*, Det.: *J. Garrido and C. Olivares s.n.* (COFC 25532). Posadas: Sierra de Hornachuelos, Parque Natural, rancho Los Ciervos III, 21-III-1997, Leg.: *A. Ortiz*, Det.: *J. Garrido s.n.* (COFC 25533). Cardena: coto Yegüerizo, 10-VI-1998, *J. C. Salamanca and A. Sánchez s.n.* (COFC 26982). Cardena: coto El Águila, 04-III-1998, *J. M. Muñoz and J. Quijada s.n.* (COFC 26983). Cardena: Finca Mañuelas, La Poveda, 30S 379989 4230621, 04-V-2017, Leg.: *M. López, M^a.C. Estrada and M. Coletto*, Det.: *J. López Tirado s.n.* (COA 57859). La Granjuela: Laguna Peña la Zorra, 03-XI-2005, Leg.: *A. Pujadas, L. Plaza and C. Burgarella*, Det.: *J. López Tirado s.n.* (COA 47469). Guadalcazar: Finca La Dehesilla, a la derecha de la pista hacia El Hecho, 186 m, zona encharcable entre el majadal con *Scirpoides holoschoenus*, *Myrtus communis* y *Cistus monspeliensis*, 08-XII-2016, Leg.: *M. López*, Det.: *M. López s.n.* (COA 57699). Los Blázquez: arroyo Tolote, 15-XII-2002, Leg.: *C. Burgarella and L. Plaza*, Det.: *C. Burgarella s.n.* (COA 32358). Belalcázar: arroyo Torilejo, 12-XII-2002, Leg.: *L. Plaza and C. Burgarella*, Det.: *C. Burgarella s.n.* (COA 32359). Córdoba: Los Villares, charca frente campo de golf, 09-II-2003, Leg.: *L. Plaza and P. Blanco*, Det.: *L. Plaza s.n.* (COA 32569). Córdoba: Los Villares, pista que va al camping, borde de pista, 09-II-2003, Leg.: *L. Plaza and P. Blanco*, Det.: *L. Plaza s.n.* (COA 32571). Hinojosa del Duque: Arroyo Galapagar, 06-II-2003, Leg.: *C. Burgarella, J. Algarra and L. Plaza*, Det.: *C. Burgarella s.n.* (COA 32572). Villaviciosa de Córdoba: Entre los ríos Guadiatillo y Cabrillas, 18-II-1980, Leg.: *Domínguez, Galiano and Varela* (SEV 165710). Córdoba: Río Guadiato, casa de los Borres, 6-III-1980, *Ruiz de Clavijo and J. Varela* (SEV 165722). Córdoba: Cerro Muriano, llanos del Conde, 16-II-1978, Leg.: *J. A. Devesa*, Det.: *A. E. Salvo* (SEV 98768). Cardena: Venta de Cerezo, arenas graníticas encharcadas, 4-III-1977, Leg.: *J. A. Devesa*, Det.: *B. Cabezudo and J. A. Devesa* (SEV 34246). Córdoba: Trassierra, Las Jaras, pizarras, 16-IV-1978, Leg.: *E. Domínguez, E. F. Galiano and al.*, Det.: *A. E. Salvo* (SEV 98766-B). Córdoba: Orillas del Río Guadiato, en el tramo comprendido entre carretera a Villaviciosa y arroyo del Bejarano, esquitos, 4-V-1978, Leg.: *J. M. Muñoz, E. Ruiz de Clavijo and al.*, Det.: *A. E. Salvo* (SEV 100709). Adamuz: La Sierrezuela, 23-II-1979, Leg.: *E. Domínguez and al.*, Det.: *A. E. Salvo* (SEV 100785). Pozoblanco: carretera comarcal 421, km 9, 20-IV-1979, Leg.: *M. L. Díaz, P. Fernández and J. M. Muñoz*, Det.: *A. E. Salvo* (SEV 100712). Córdoba: Trassierra, Las Jaras, pizarras, 16-IV-1978, Leg.: *E. Domínguez, E. F. Galiano, J. M. Muñoz and al.*, Det.: *A. E. Salvo* (SEV 100713). Pozoblanco: km 24 de la carretera CO 421, pinar sobre carbonífero, 13-IV-1982, Leg.: *A. Aparicio, J. García and S. Silvestre*, Det.: *A. E. Salvo* (SEV 101395). Guadalcazar: arcenes de la carretera a Fuencubierta, poco después del arroyo de la Marota, 16-III-1979, Leg.: *J. M. Muñoz and J. Varela*, Det.: *A. E. Salvo* (SEV 100786). Montoro: Sierra Morena, Los Patalos, suelo arenoso encharcado temporalmente, 550 m, 04-V-1992, *M. Melendo* (GDAC 41883).

ISOETES DURIEUI: El Viso: Arroyo del Romano, cerro Membrillo, 14-IV-1986, Leg.: *M. J. Jiménez*, Det.: *N. Tobes s.n.* (COFC 13931). Hornachuelos: Dehesa entre caserío San Bernardo y cortijo Santa Cruz, 27-II-1997, Leg.: *R. Martínez and A. Ortiz*, Det.: *J. Garrido and C. Olivares s.n.* (COFC 25433). El Viso: Arroyo del Romano, 12-II-1997, *J. Garrido and C. Olivares s.n.* (COFC 25432-1). Posadas: cortijo Las Platas, 02-IV-1997, *R. Martínez and A. Ortiz s.n.* (COFC 25534-2). Hornachuelos: Entre el caserío San Bernardo y el cortijo Santa Cruz, 06-III-1997, Leg.: *J. Garrido, R. Martínez and A. Ortiz*, Det.: *J. Garrido and C. Olivares s.n.* (COFC 25434). Cardena: Finca Mañuelas, La Poveda, 30S 379989 4230621, 04-V-2017, Leg.: *M. López*,

- M^a.C. Estrada and M. Coletto*, Det.: *M. López s.n.* (COA 60384). Belalcázar: Arroyo Torilejo, 12-XII-2002, Leg.: *C. Burgarella and L. Plaza*, Det.: *C. Burgarella s.n.* (COA 32357). **ISOETES LONGISSIMA**: Belalcázar: Ctra. comarcal 451, cercanías de Belalcázar, 31-V-1983, *A. M. Prados and E. Ruiz de Clavijo s.n.* (COFC 13936). Belalcázar: Ctra. entre el municipio y la estación, 23-XI-1984, *R. Durán, M. Jiménez, A. M. Prados and E. Ruiz de Clavijo s.n.* (COFC 13937). Belalcázar: Ctra. Belalcázar - estación de Belalcázar, arroyo (VH-17), 04-V-1985, *M. J. Jiménez and J. Tabares s.n.* (COFC 13938). Belalcázar: Ctra. Belalcázar - estación de Belalcázar, 23-XII-1984, *R. Durán, M. J. Jiménez, A. M. Prados and E. Ruiz de Clavijo* (COFC 32525). Belalcázar: Cerca estación Belalcázar, arroyo Guadamatilla, Cañada del Caballo, 400 m, 03-XI-2005, Leg.: *A. Pujadas, L. Plaza and C. Burgarella*, Det.: *A. Pujadas s.n.* (COA 47474). Belalcázar: Entre Belalcázar y Estación de Belalcázar, 31-V-1983, *Ruiz de Clavijo and A. Prados* (MGC 11577). Estación de Belalcázar, arroyo Guadamatilla, 30-V-1984, Leg.: *J. Arroyo, J. A. Mejías and S. Talavera*, Det.: *J. López Tirado* (SEV 207096). Cardeña: Sierra Morena, arroyo Corcobada, suelo temporalmente encharcado en terreno granítico, 720 m, 21-V-1997, *M. Melendo* (GDAC 42231). **ISOETES DELILEI**: Córdoba: Arroyo Rabanales, junto a la vereda de La Alcaidía, 160 m, 18-V-1996, Leg.: *A. Ortiz and R. Pinilla*, Det.: *J. Garrido and C. Olivares s.n.* (COFC 25430). Córdoba: Arroyo Rabanales, junto a la vereda de La Alcaidía, 160 m, 30-V-1996, Leg.: *J. Garrido, A. Ortiz and R. Pinilla*, Det.: *J. Garrido and C. Olivares s.n.* (COFC 25431). Hinojosa del Duque: Arroyo Galapagar en intersección con la ctra. a la estación de Mármol, km 13 aprox., 12-V-1996, Leg.: *C. Olivares and R. Porras*, Det.: *J. Garrido and C. Olivares s.n.* (COFC 25428). Hinojosa del Duque: Arroyo Galapagar en intersección con la ctra. a la estación de Mármol, km 13 aprox., 13-III-1996, *J. Garrido and C. Olivares s.n.* (COFC 25427). Hinojosa del Duque: Arroyo Galapagar en intersección con la ctra. a la estación de Mármol, km 13 aprox., 13-III-1996, *J. Garrido and C. Olivares s.n.* (COFC 25426). Hinojosa del Duque: Arroyo Galapagar en intersección con la ctra. a la estación de Mármol, km 13 aprox., 12-V-1996, Leg.: *C. Olivares and R. Porras*, Det.: *J. Garrido and C. Olivares s.n.* (COFC 25429). Los Blázquez: cerca del Río Zújar, Chozo Blanco, 30S 280309E 4259137N, 521 m, 27-III-2011, Leg.: *M. López, E. López and R. Pulido*, Det.: *J. López Tirado s.n.* (COA 55147). Guadalcázar: Pista al parque periurbano “El Hecho”, finca La Dehesilla, charca temporal con *Marsilea strigosa*, 21-XI-2010, Leg.: *M. López*, Det.: *J. López Tirado s.n.* (COA 51719). Adamuz: Ctra. Adamuz a Villanueva, km 33-35, 25-V-2003, *C. Burgarella and M. de Navascués s.n.* (COA 33443). Hinojosa del Duque: Carretera del Mármol, junto al arroyo Galapagar, 28-III-1978, *M. L. Díaz* (MGC 12716). Entre Hinojosa del Duque y Estación del Mármol, 20-IV-1979, *M. L. Díaz* (MGC 11576). Hinojosa del Duque: Carretera del Mármol, junto al arroyo Galapagar, 28-III-1978, *M. L. Díaz* (MGC 11553). Valsequillo: arroyo Galapagar, 30-V-1984, Leg.: *J. Arroyo, J. A. Mejías and S. Talavera*, Det.: *J. López Tirado* (SEV 207094). Valsequillo: arroyo Galapagar, 30-V-1984, Leg.: *J. Arroyo, J. A. Mejías and S. Talavera*, Det.: *J. López Tirado* (SEV 207213). Hinojosa del Duque: Carretera del Mármol, km 10, junto al arroyo Galapagar, granodioritas, 14-V-1978, Leg.: *M. L. Díaz*, Det.: *A. E. Salvo* (SEV 100702). Hinojosa del Duque: Arroyo Galapagar (en su intersección con la carretera del Mármol), 20-IV-1979, Leg.: *M. L. Díaz, P. Fernández and J. M. Muñoz*, Det.: *A. E. Salvo* (SEV 100703). Hinojosa del Duque: Carretera del Mármol, junto a Galapagar, granodioritas, 28-III-1978, Leg.: *M. L. Díaz*, Det.: *A. E. Salvo* (SEV 100706). Cardeña: Sierra Morena, arroyo Corcobada, cauce del arroyo en terreno granítico, aguas superficiales y estacionales, 720 m, 21-V-1997, *M. Melendo* (GDAC 42229). Cardeña: Sierra Morena, arroyo Corcobada, cauce del arroyo en terreno granítico, aguas superficiales y estacionales, 720 m, 21-V-1997, *M. Melendo* (GDAC 42230). La Granjuela: Los Pedroches, Laguna Peña de la Zorra, 30STH94, 23-V-2007, Leg.: *L. Medina, A.J. Delgado and M.L. Jiménez*, Det.: *A.J. Delgado* (GDA 52920). **DIFFERENT GENUS TO ISOETES**: Fuente Obejuna: Carretera Fuente Obejuna-La Granjuela, pequeña cantera invadida por *Typha*, 30S 292089 4243232, 16-V-2019, Leg.: *M. López, M^a.C. Estrada and D. García*, Det.: *J. López Tirado s.n.* (COA 59296). Villanueva del Duque: Dehesa Boyal, 30S 323975E 4250785, 581 m, 11-VI-2019, Leg.: *M. López, M^a.C. Estrada and D. García*, Det.: *J. López Tirado s.n.* (COA 56369).