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Ludwigia peploides subsp. *montevidensis*, a new alien taxon for the flora of Greece and the Balkans

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Ludwigia peploides (Kunth) Raven subsp. *montevidensis* (Spreng) Raven is a taxon native to South America extending from Brazil and Uruguay to Argentina and Chile. It was introduced and established in east Australia and New Zealand and locally naturalized in west Europe. This taxon is herein reported as a new alien taxon for Greece and the Balkans. It was collected in 2001 from western Greece in three localities of the lake Lysimachia covering a very small area (0.7 ha). *Ludwigia* populations participate in two well-distinguished vegetation communities: a) a reed vegetation of *Phragmites australis - Ludwigia peploides* subsp. *montevidensis* comm. and b) a wet meadow vegetation of *Ludwigia peploides* subsp. *montevidensis - Paspalum paspaloides* comm. Through ordination analysis, soil moisture, pH, electric conductivity, organic matter (%C) and % $CaCO_3$ were identified as underlying environmental factors determining the composition of *Ludwigia peploides* plant communities. Comments are made on the possible modes of introduction of the taxon and its native and secondary distribution.

Key words: alien taxon, *Ludwigia*, Onagraceae, Greece, Balkans.

INTRODUCTION

The only presently known *Ludwigia* species occurring in Greece is *Ludwigia palustris* which is considered as a rare vascular wetland plant (Raus, 1991). *Ludwigia palustris* is recorded from fourteen wetland sites that cover almost all the floristic regions of Greece, except for the East Aegean Islands, and south and north Pindos (Raus, 1991). Populations of *L. palustris* have been recorded since 1908, in the lakes Trichonida and Lysimachia, Aetolia (Maire & Petitmengin, 1908). *Ludwigia peploides* is a species introduced from America and its presence in Greece is noteworthy for the Balkan Peninsula and southern Europe, since in Tutin *et al*. (1968-1980) this species is recorded as occurring only in France. Recently, *L. peploides* was reported in southern Turkey (Göktürk & Sümbül, 1998).

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Concerning the native distribution range of *L. peploides* subsp. *montevidensis*, it is a common taxon in South America, extending from Brazil and Uruguay to Argentina and Chile (Raven, 1963; Fabris, 1966; Tutin *et al*., 1968-1980; Zuloaga & Morrone, 1999). It is possibly introduced to Australia (where it is unclear whether it was an early introduction), with occurrences along the coast from Queensland, through New South Wales and Victoria to the Murray River, penetrating the southern interior along major rivers. Raven (1963) could not distinguish a great part of Australian material from the temperate South American specimens of *L. peploides* subsp. *montevidensis*; therefore, he referred to them all as belonging to this taxon. It is locally established around Auckland in New Zealand and widely naturalized in rivers of north-western Europe, particularly in France and Belgium.

Ludwigia peploides subsp. *montevidensis* is a floating aquatic or procumbent, terrestrial, perennial herb with stems rooting at the nodes. It differs from other

TABLE 1. Taxonomic characters for comparison between *Ludwigia palustris* and *Ludwigia peploides* subsp. *montevidensis* (Munz, 1942; Tutin *et al.*, 1968-1980)

Taxonomic characters	***Ludwigia palustris***	***Ludwigia peploides* subsp. *montevidensis***
Stems	0.03 - 0.5 m glabrous, creeping	0.5 - 1 (-1.5) m, freely branched, mostly horizontal, but often ascendant at flowering tips. Plants pilose or densely covered with long, spreading, viscid hairs, except sometimes on floating stems
Leaves	0.7 - 0.45 mm, opposite, narrowly obovate	1.2 - 9 (-9.5) × 0.5 - 3 cm vilous, alternate, entire, base cunate, apex acute. Juvenile leaves often lanceolate, mature leaves broadly oblanceolate or elliptical
Flowers	1 (-2) in the leaf axils, subsessile	Solitary, born in upper leaf axils
Sepals	4, 1.4 - 2 × 0.8 - 1.8 mm	5, (4.5-) 6 - 9 (-10) × 1.5 - 2.5 (-3) mm, acute, lanceolate to narrowly triangular or deltoid, villous or subglabrous
Petals	Absent	(8-) 10 - 15 × (4-) 5 - 8 mm, bright yellow, entire obovate, sometimes slightly emarginate at the apex, glabrous
Stamens	4, filaments 0.5 - 0.6 mm	10, in 2 whorls filaments 2-5.5 mm
Capsule	2 - 5 × 2 - 3 mm, glabrous, obscurely 4-angled, with green bands on the angles	15-25 mm long, cylindrical, bearing 10 inconspicuous vertical reticulations
Seeds	0.6 - 0.9 × 0.3 mm, multi-seriate in each loculus, free from endocarp	1-13 mm, uniseriate in each locule, free or embedded in endocarp

subspecies of *L. peploides* in having bracteoles near the middle, as opposed to the base of the fruit capsules. A further distinguishing characteristic of this taxon are the long, spreading, viscid hairs which secrete a sticky material. *Ludwigia peploides* subsp. *montevidensis* is a taxonomically distinct species from *L. palustris*, as shown in Table 1. The objectives of the present paper were:

a) to report the first occurrence of *L. peploides* subsp. *montevidensis* in Greece and give detailed information on the ecological conditions of its habitats,
b) to provide an ecological interpretation of the distinguished communities where *L. peploides* occurs, and
c) to provide a synoptic literature review for the taxon.

MATERIALS AND METHODS

The first collections of *L. peploides* subsp. *montevidensis* were made by the Greek authors of this paper, in July 2001, in three localities of the lake Lysimachia (in the western chain of Greek wetlands) (Fig. 1). This research constitutes part of a broader research currently in progress by the first author in the frame of his doctoral thesis entitled "Ecology and conservation management of the reed thickets and wet meadows in lakes of Aitoloakarnania". After identifying the taxon as an interesting new finding of *Ludwigia*, the material was sent to the Royal Botanic Gardens of Kew, for confirmation. A voucher specimen from the collection site is preserved at the Herbarium of the Department of Environmental and Natural Resources Management, University of Ioannina, Greece.

In July 2001 and 2002, 15 relevés were made according to the Braun-Blanquet method (Westhoff & van der Maarel, 1973; Kent & Coker, 1992), covering the distribution area of *Ludwigia* in the lake Lysimachia. In plots of 9 m^2 for the wet meadow vegetation and 50 m^2 for the reed thickets, cover-abundance was estimated using the extended (9-point) Braun-Blanquet scale (Barkman *et al*., 1964).

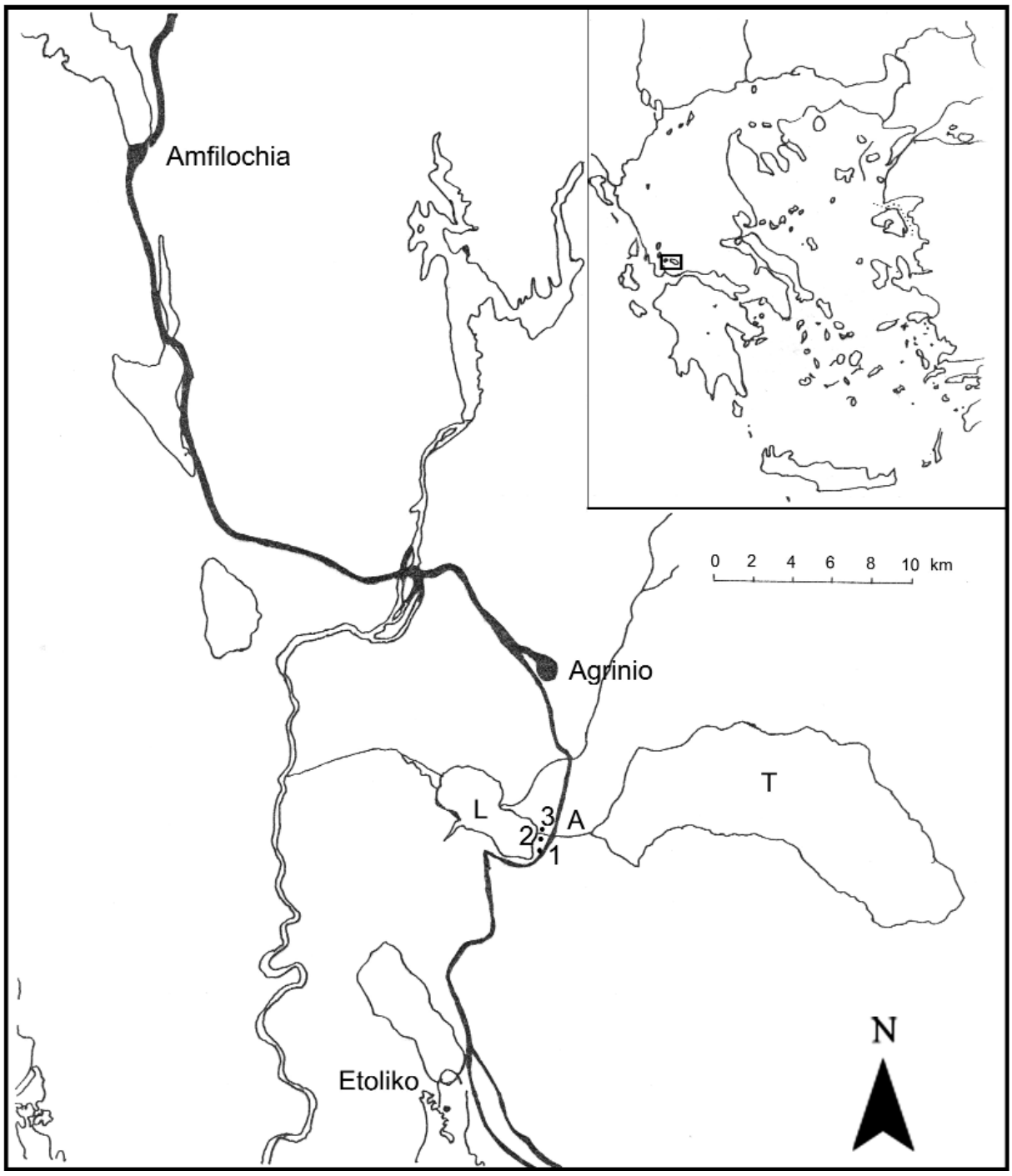

FIG. 1. Distribution map of the newly reported populations of *Ludwigia peploides* subsp. *montevidensis* in the lake Lysimachia (●). The location numbers (1, 2, 3) refer to populations of this taxon in the lake Lysimachia (see text). L: lake Lysimachia, T: lake Trichonida, A: channel connecting the two lakes.

Taxa nomenclature used in this paper, except for *Ludwigia*, follows that by Tutin *et al*. (1968-1980, 1993). Soil moisture was measured for each relevé in the field and 15 soil samples (one from each relevé) were brought to the Laboratory of Ecology and Biodiversity Management (University of Ioannina, Greece) for texture analysis with the categories sand, silt, clay (expressed as % weight), and for measurements of electric conductivity, pH, organic carbon (% C), $CaCO_3$ (%) and pH in 1:1 soil-water solution. The

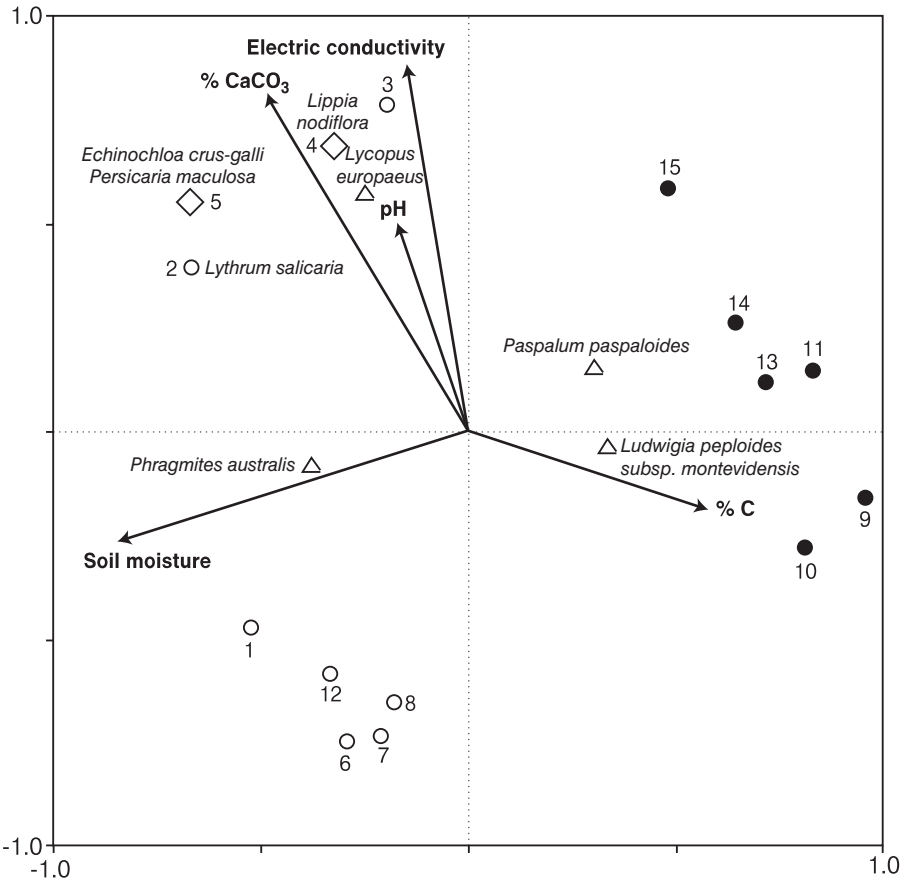

FIG. 2. CCA triplot ordination diagram of the first two canonical axes with relevés (o, •), plant species (△), plant species overlapping relevés (◇) and environmental variables (arrows) of the *Ludwigia peploides* subsp. *montevidensis* communities. For relevé numbers and their assignment in the two vegetation communities see Table 2.

relevés were classified using TWINSPAN (Hill, 1979). Ordination analyses were carried out using the CANOCO package (Ter Braak & Šmilauer, 1998). Soil moisture, pH, % $CaCO_3$, % C and electric conductivity were related to the first two axes of a direct Canonical Correspondence Analysis (CCA) performed on the relevés as illustrated in Fig. 2.

RESULTS AND DISCUSSION

Nomenclature

Ludwigia peploides (Kunth) Raven subsp. *montevidensis* (Spreng) Raven (1963).

Munz (1942) revised the New World species of *Jussiaea*. In this work, Munz considered *J. montevidensis* Spreng as a variety of *J. repens* L. and made the following new combination: *J. repens* L. var. *montevidensis* (Spreng) Munz. Hara (1953) combined *Ludwigia* and *Jussiaea* into a single genus which, following the rules of the Code of Botanical Nomenclature, was named *Ludwigia*. Many of the necessary new combinations were also made in this article. Simultaneously, Hara (1953) sunk *J. repens* L. and five of its varieties including var. *montevidensis*, into *L. adscendens* (L.) Hara var. *montevidensis* (Spreng) Hara. Raven (1963) revised the Old World *Ludwigia*, maintained *J. repens* L. as a synonym of *L. adscendens* (L.) Hara, but changed the rank of the five varieties to subspecies and transferred them to alternative species. Therefore, *L. adscendens* var. *glabrescens*, var. *montevidensis*, var. *peploides* and var. *stipulacea* all became subspecies of *L. peploides* (Kunth) Raven.

The type of taxon known today as *L. peploides* (Kunth) Raven subsp. *montevidensis* (Spreng) Raven was originally described in 1825 as *J. montevidensis* Spreng on the basis of a collection made by Sello from Montevideo in Uruguay.

Synonyms: *Jussiaea montevidensis* Spreng; *J. repens* L. var. *montevidensis* (Spreng) Munz; *L. adscendens* (L.) Hara var. *montevidensis* (Spreng) Hara.

Occurrence in Greece

Ludwigia peploides subsp. *montevidensis* was found to cover a small surface area (0.7 ha) in the lake Lysimachia (western Greece, Aitoloakarnania) in three localities: 1: 21°24′ 32′′ N, 38° 32′ 54′′ E; 2: 21° 24′ 41′′ N, 38° 32′ 82′′ E; 3: 21° 24′ 90′′ N, 38° 33′ 02′′ E (Fig. 1). The lake Lysimachia constitutes together with lake Trichonida one of the proposed Sites of Community Interest (pSCI) included in the European Ecological Network "Natura 2000" of Greece (GR2310009: Lakes Trichonida and Lysimachia). The habitat area of *L. peploides* subsp. *montevidensis* corresponding to localities 1 and 2, is seasonally flooded. In winter, the habitat of *L. peploides* subsp. *montevidensis* is flooded due to water level increase of the lake. In summer, the area is subjected to intensive human disturbances (cultivation of tobacco and corn in the vicinity of the studied populations), and additional pressures to expand the cultivated land. Locality 3 represents moderately inclined banks of a channel connecting lakes Lysimachia and Trichonida. Here, *L. peploides* subsp. *montevidensis* forms dense mats covering the banks, with floating stems in the main water body. The total population of the species in the three collection localities consisted of ca. 10,000 individuals (2001).

Habitat conditions and vegetation types

Ludwigia peploides subsp. *montevidensis* rapidly colonizes areas of still, 2-3 m deep fresh water. The plants initially establish on sandy or gravely banks or rocky alluvia, and extend long, spreading, floating stems into the water, ultimately forming dense mats that cover the water surface (this is the case in locality 3). In the lake Lysimachia, this taxon occurs also in areas seasonally flooded for about six to eight months (localities 1, 2). These expanses can cause environmental problems as they eventually disrupt channel flow and encourage stagnation. In addition, large expanses of a single species can eventually put pressure on the niches of indigenous species. *Ludwigia peploides* subsp. *montevidensis* reproduces with great efficiency (a fragment of stem or adventitious root very quickly develops into a mature individual).

TABLE 2. Phytosociological table of *Ludwigia peploides* subsp. *montevidensis* communities in Greece (lake Lysimachia). PhL: *Phragmites australis - Ludwigia peploides* subsp. *montevidensis*, LP: *Ludwigia peploides* subsp. *montevidensis - Paspalum paspaloides*

Community	PhL	PhL	PhL	PhL	PhL	PhL	PhL	PhL	PhL	LP	LP	LP	LP	LP	LP
Altitude (m)	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Area (m^2)	50	50	50	50	50	50	50	50	50	9	9	9	9	9	9
Relevé number	4	3	1	2	6	5	7	8	12	10	9	11	13	14	15
Ludwigia peploides subsp. *montevidensis*	**2a**	**2b**	**3**	**3**	**3**	**2b**	**3**	**4**	**3**	**5**	**5**	**5**	**5**	**5**	**5**
Phragmites australis	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	.	.	.	.	.	.
Paspalum paspaloides	.	2b	.	.	+	3	2a	2a	.	**3**	**2b**	**2b**	**2b**	**2a**	**2b**
Lycopus europaeus	3	4	.	.	+	.	+	+	2a	.	.	.	.	.	.
Lippia nodiflora	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Persicaria maculosa	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Lythrum salicaria	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.
Echinochloa crus-galli	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.

TABLE 3. Soil characteristics of the *Ludwigia peploides* subsp. *montevidensis* communities

Community	No of relevés	C (%)	pH	Electric conductivity (µs/cm)	$CaCO_3$ (%)	Texture (%) Clay	Silt	Sand	Soil moisture (%)
1 (PhL)	9	5.7±2.2	7.5±0.5	260.4±107.1	10.8±8.9	7.8±3.4	21.5±9.8	70.5±11.9	30.8±4.4
2 (LP)	6	7.8±0.0	7.4±0.3	263.2±92.8	4.8±6.9	12.3±4.5	13.7±2.1	74.0±2.4	17.6±1.6

From the classification results on the 15 relevés from localities 1 and 2, it became evident that *L. peploides* subsp. *montevidensis* participates in the following two vegetation communities clearly distinguished in the study area (Table 2, Fig. 2):

a) *Phragmites australis - Ludwigia peploides* subsp. *montevidensis* comm. (9 relevés, Table 2), growing on loamy-sandy soils with an average moisture of 30.8%, average organic matter of 5.7%, average pH of 7.5 and average electric conductivity of 260.4 μs/cm (Table 3).

b) *Ludwigia peploides* subsp. *montevidensis - Paspalum paspaloides* comm. (6 relevés, Table 2), growing on loamy-sandy soils with an average moisture of 17.6%, average organic matter of 7.8%, average pH of 7.4 and average electric conductivity of 263.2 μs/cm (Table 3).

Ludwigia peploides subsp. *montevidensis* participates as a character taxon in the composition of two communities (Table 4), of which one represents stands of a typical reed thicket, with many similarities to the ecological conditions of the *L. palustris* communities in Kalodiki Fen in north-western Greece (Typho-Phragmitetum typhetosum angustifoliae) and in Skiathos of the Sporades island complex (*Ludwigia palustris - Typha angustata* comm.). The second community resembles the *Phragmito-Magnocaricetea* frame community of *Phalaris arundinacea* occurring in Kalodiki Fen, where *L. palustris* participates as a differential species, the *L. palustris* comm. from Kalodiki Fen (Dimopoulos *et al*., 2005), and the *L. palustris - Potamogeton natans* comm. from Skiathos island (Economidou, 1969; 1975).

Relation between species composition and environmental parameters

The CCA results with soil moisture, pH, electric conductivity, % C and % $CaCO_3$ as environmental parameters are shown in the CCA triplot of Fig. 2. According to Table 5, axes 1 and 2 represent the greatest amount of explanatory value (41 and 9%, respectively). Axis 3 and the following were not interpreted. The CCA triplot of samples (relevés), species and environmental variables (Fig. 2) based on the first two axes explains 60.8% of the variance (inertia) in the species data, and 97.3% of the variance in the weighted averages of the species with respect to the environmental variables.

Of the examined environmental variables, the longest arrows represent soil moisture, electric conductivity, % C and % $CaCO_3$, meaning that these are

TABLE 4. Literature synopsis on the assignment of *Ludwigia palustris* and *Ludwigia peploides* subsp. *montevidensis* in plant communities of Greece in relation to their national distribution

Syntaxon	Character - Differential - Constant species	Companion species	Geographical distribution
Ludwigia palustris			
Ranunculus rionii - Callitriche brutia comm.		x	Kalodiki (Sarika-Hatzinikolaou *et al.*, 2003)
Myriophylletum alterniflori		x	Kalodiki (Sarika-Hatzinikolaou *et al.*, 2003)
Frame community of *Phalaris arundinacea*- [Phragmito-Magnocaricetea]	x		Kalodiki (Dimopoulos *et al.*, 2005)
Typho-Phragmitetum typhetosum angustifoliae	x		Kalodiki (Dimopoulos *et al.*, 2005)
Ludwigia palustris comm.	x		Kalodiki (Dimopoulos *et al.*, 2005)
Ludwigia palustris - Potamogeton natans comm.	x		Skiathos (Economidou, 1969; 1975)
Ludwigia palustris - Typha angustata comm.	x		Skiathos (Economidou, 1969; 1975)
Ludwigia peploides subsp. *montevidensis*			
Phragmites australis - Ludwigia peploides subsp. *montevidensis* comm.	x		Lake Lysimachia (present contribution)
Ludwigia peploides subsp. *montevidensis - Paspalum paspaloides* comm.	x		Lake Lysimachia (present contribution)

TABLE 5. Correlations of environmental factors (soil moisture, pH, electric conductivity, % C, % $CaCO_3$) with the first two CCA axes, Eigenvalues of the ordination axes and sum of all unconstrained Eigenvalues (total inertia) for CCA analysis of the plant communities with *Ludwigia peploides* subsp. *montevidensis* in Greece

Environmental variable	**Axis 1**	**Axis 2**
Soil moisture	-0.80	-0.19
pH	-0.17	0.36
Electric conductivity	-0.14	0.63
% C	0.55	-0.14
% $CaCO_3$	-0.46	0.58
Eigenvalue	0.41	0.09
Species-environment correlation	0.93	0.71
Cumulative percentage variance of species data	49.2	60.8
Cumulative percentage variance of species-environment relation	78.8	97.3
Sum of all Eigenvalues	0.82	
Sum of all canonical Eigenvalues	0.51	
Total inertia	0.82	

more strongly correlated with the ordination axes (axis 1: soil moisture, % C; axis 2: electric conductivity, $CaCO_3$) and more closely related to the pattern of community variation and the variation in species composition (as represented by the relevés of the distinguished plant communities) shown in the ordination diagram (Fig. 2). Along axis 2, electric conductivity and % $CaCO_3$ explain 63 and 58% of the species composition, respectively, while along axis 1, soil moisture and organic matter (% C) explain 80 and 55% of the species composition, respectively (Table 5). From the upper left side to the lower left side of the ordination diagram, a gradient from less to more moist conditions and from relatively nutrient-rich to more nutrient-poor species composition can be distinguished. *Ludwigia peploides* subsp. *montevidensis* which is a character taxon of the *L. peploides* subsp. *montevidensis - Paspalum paspaloides* comm., appears on the right side of the ordination diagram in the direction of increased organic matter.

Native and secondary distribution

An interesting phytogeographical question is related to the mode that the examined taxon achieved this disjunctive distribution. Raven (1963) comments that *L. peploides* subsp. *montevidensis* may have been introduced to Australia, but cites specimens from the British Museum (BM) as evidence that this taxon was collected very early, approximately 15 years after the first permanent habitation of this area and from the vicinity of the Botany Bay, an area with no connection to South America. However, Raven also notes that by 1860, the plant was abundant throughout at least New South Wales, this rapid spread supporting the idea that it was introduced. Judging by the rapid spread of this plant in Europe in the last 100 years, this may well be the case.

Possible modes of introduction

Portions of the plant have been recorded as being carried on the plumage of birds (Salanon, 1999) for several miles between bodies of water. This, together with the transfer of plant material by boats, are the main methods by which this taxon is thought to have spread throughout north-western Europe over the last 30 years. The first record on the introduction of an unknown species of *Ludwigia* in France was made in Montpellier in 1820's where it was used as a decorative plant for small ponds and waterways. Rapidly, there were reports of *L. peploides* subsp. *montevidensis* and *L. grandiflora* (Michaux) occurring in the wild throughout the Langeudoc region. For many years the above mentioned taxa were contained in this region until approximately 30 years ago, when these species spread out and colonized rivers in most of France and Belgium.

Ludwigia peploides subsp. *montevidensis* is not as aggressive (colonizer) as the closely related *L. grandiflora*. However, it is a highly invasive weed species in lakes and rivers and in some cases (e.g. France) there is an intensive programme to eradicate it from certain areas.

In lake Lysimachia, it is possible that this taxon was introduced by birds, as the lake is a station for migratory birds (Dafis *et al*., 1996). Relevant vegetation monitoring is currently in progress within the potential distribution areas of *L. peploides* subsp. *montevidensis* (along river and rivulet banks and lakes of western Greece), with the aim to provide evidence on the dynamism and the aggressive expansion character of this taxon.

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