NORTH-WESTERN JOURNAL OF ZOOLOGY 13 (1): 128-135
Article No.: e161803

http://biozoojournals.ro/nwjz/index.html

Earthworms of Crete (Oligochaeta: Lumbricidae, Acanthodrilidae): new records, remarks and biogeographical review

Tímea SZEDERJESI

Department of Zoology, Plant Protection Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, P.O. Box 102, H-1525 Budapest, Hungary.
E-mail: t.szederjesi@gmail.com

Received: 03. September 2015 / Accepted: 28. January 2016 / Available online: 30. March 2016 / Printed: June 2017

Abstract. In the present study results of the recent earthworm collecting trip to Crete are presented. 16 species and subspecies were recorded, of which eight (*Allolobophora chlorotica chlorotica*, *Aporrectodea georgii*, *Ap. rosea*, *Dendrobaena byblica olympiaca*, *D. pantaleonis*, *Eisenia ebneri*, *E. fetida* and *Murchieona minuscula*) proved to be new for the fauna of Crete. With those records, the number of known species from the island increases to 20, while the presence of two species in Crete remained in question. All the earlier studies on the Cretan earthworm fauna are reviewed, short remarks are given to the previously recorded uncertain species and occurrences. Biogeographical evaluation of the earthworm fauna revealed that the island is dominated by peregrine species (38.1-47.6%), real endemism is not seen nevertheless only two narrower Balkanic endemic species (*D. byblica olympiaca*, *E. ebneri*) exist in Crete.

Key words: earthworms, Lumbricidae, Crete, new records, biogeography.

Introduction

Covering an area of 8,336 km² Crete is the fifth largest island in the Mediterranean. It lies 95 km from mainland Greece, 179 km from the continent of Asia, 284 km from the continent of Africa and separates the Aegean from and the Libyan Sea. Crete has three main mountain massifs: the western part is dominated by Lefka Ori, and Dikti extending to the east, and Psiloritis, which rises in central Crete and at 2,456 m is the highest peak on the island. The climate is mainly Mediterranean, the southern coast falls within the North African climatic zone.

Regarding its tectonic history, Crete was part of the Aegeid plate, until the first transgression of the Mediterranean Sea into the Aegean area in the Tortonian (~11 Mya) (Steininger & Rögl 1984). During the Messinian Salinity Crisis (MSC) (5.96-5.33 Mya), the Mediterranean Sea dried up and created an opportunity for the reconnection of Crete to the Peloponnese, while it remained isolated by saline deserts and saline lakes from the rest of the Aegean region. Crete became completely isolated following the MSC period (Poulakakis et al. 2014).

There has been little research on earthworm fauna of Crete , so far there have been only four studies of the island. It was Michaelsen (1902) who first published data from Crete and altogether he recorded five species, namely *Eiseniella tetraedra* f. *typica* [=*Eiseniella tetraedra*], *Eisenia veneta* f. *typica* [=*Dendrobaena veneta*], *Dendrobaena ganglbaueri* var. *byblica* [=*Dendrobaena byblica*], *Eophila patriarchalis* [=*Helodrilus patriarchalis*] and *Octolasium complanatum* [=*Octodrilus complanatus*]. After his work, Cognetti (1906) increased the species number by indicating the presence of *Helodrilus* (*Allolobophora*) *caliginosus* [=*Aporrectodea caliginosa*], *Helodrilus* (*Dendrobaena*) *ganglbaueri* var. *annectens* [=*Fitzingeria annectens*] and *Eisenia veneta* var. *hibernica* [=*Dendrobaena hortensis*]. The third paper was written by Černosvitov (1934), who recorded *Eisenia alpina* f. *typica* [=*Dendrobaena alpina alpina*] and described *Eiseniella tetraedra* mut. *intermedia* [=*Eiseniella tetraedra*] from the island. First organized earthworm collecting trip to the island was did not take place until 2013, when nine species were recorded (Szederjesi 2015), of which three (*Ap. jassyensis*, *Lumbricus rubellus* and *Microscolex dubius*) proved to be new for the island's fauna. When these data are included, the number of valid earthworm species recorded from Crete increased to 12.

The aim of this paper is to present the results of the recent collecting trip to Crete with notes on some species and to give a review of the biogeographical aspects of the earthworm fauna on the island.

Material and methods

Earthworm collecting was performed using the diluted formaldehyde method (Raw 1959), complemented with

digging and searching under stones and the bark of fallen logs. The specimens were killed and fixed in 96% ethanol, then transferred into 75% ethanol and deposited in the earthworm collection of the Hungarian Natural History Museum (HNHM). Species with taxonomic significance were placed in 96% ethanol for later molecular studies. Sampling localities in Crete are shown in Figure 1 and Table 1, the site numbers in the text are indicated in italics.

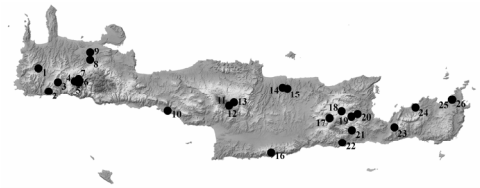

Figure 1. Collecting sites in Crete.

Biogeographical evaluation was given following Csuzdi & Zicsi (2003), Csuzdi et al. (2011) and Pavlíček & Csuzdi (2016).

Results

Family Lumbricidae Rafinesque-Schmaltz, 1815

***Allolobophora chlorotica chlorotica* (Savigny, 1826)**

Enterion chloroticum Savigny, 1826: 182.

Allolobophora chlorotica chlorotica: Csuzdi & Zicsi 2003: 50 (for complete synonymy).

New data: HNHM/17007 1 ex., *No. 15.* HNHM/17041 1 ex., *No. 9.*

Remark. *A. chlorotica* is new for the fauna of Crete. This peregrine species is widely introduced extratropically all over the world, so it's presence on the island was expectable.

***Aporrectodea caliginosa trapezoides* (Dugès, 1828)**

Lumbricus trapezoides Dugès, 1828: 289.

?*Helodrilus* (*Allolobophora*) *caliginosus*: Cognetti 1906: 6.

Aporrectodea caliginosa: Szederjesi 2015: 144.

Aporrectodea (*Aporrectodea*) *caliginosa trapezoides*: Mršić 1991: 328 (for complete synonymy).

New data: HNHM/16989 1 ex, HNHM/16994 3 ex., *No. 13.* HNHM/16990 3 ex., *No. 11.* HNHM/16887 3 ex., *No. 12.* HNHM/17005 1 ex., *No. 5.* HNHM/17008 2 ex., *No. 10.* HNHM/17013 1 ex., *No. 16.* HNHM/17016 6 ex., *No. 4.* HNHM/17018 1 ex., HNHM/17038 4 ex., *No. 21.* HNHM/17026 1 ex., *No. 6.*

Previous occurrences in Crete: Neapoli? (Cognetti 1906), Ida Mts, Zakros, Loutraki, Orino, Agios Georgios, Omalos (Szederjesi 2015).

Remark. Re-examination of the previously recorded specimens (Szederjesi 2015) proved that all of them belong to the *trapezoides* subspecies. Unfortunately, we have not got much information on Cognetti's specimens to decide unambiguously, the only mentioned character is tubercula pubertatis stretching on 31-33.

***Aporrectodea georgii* (Michaelsen, 1890)**

Allolobophora georgii Michaelsen, 1890: 3.

Aporrectodea georgii: Szederjesi & Csuzdi 2012a: 30.

New data: HNHM/17034 2 ex., *No. 15.*

Remark. *Ap. georgii* is new for the fauna of Crete.

***Aporrectodea rosea* (Savigny, 1826)**

Enterion roseum Savigny, 1826: 182.

Aporrectodea rosea: Csuzdi & Zicsi 2003: 92 (for complete synonymy).

New data: HNHM/17006 1 ex., *No. 15.*

Remark. This peregrine species has not been recorded from Crete previously.

***Dendrobaena byblica byblica* (Rosa, 1893)**

Allolobophora byblica Rosa, 1893: 4-5.

Helodrilus (*Dendrobaena*) *ganglbaueri* var. *byblica*: Michaelsen 1902: 45.

Helodrilus (*Dendrobaena*) *gangbaueri* var. *annectens*: Cognetti 1906: 7.

Dendrobaena byblica byblica: Szederjesi 2015: 145.

New data: HNHM/17035 1 ex., *No. 15.* HNHM/17036 2 ex., *No. 14.*

Previous occurrences in Crete: Rethymno, Agia Roumeli, Nerokouros (Michaelsen 1902), Neapoli (Cognetti 1906), Agii Deka, Agios Ioannis, Moni Veni, Kakopetros, Zakros, Mirthios (Szederjesi 2015).

Remark. Cognetti (1906) recorded the presence of *Fitzingeria annectens* from Crete. This is a Carpathian endemic species (Csuzdi et al. 2011), living solely in Transylvania and in the Southern Carpathians (Szederjesi et al. 2014). It has been regarded as a synonym of *D. byblica* until Zicsi & Pop (1984) reinstated it with regard to the backward shifted male pore, which is a typical characteristic of the *Fitzingeria* species. Re-examination of Cognetti's specimens (V5016) in the Natural History Museum, Vienna revealed that they are actually *D. byblica byblica*.

***Dendrobaena byblica olympiaca* (Michaelsen, 1902)** (Fig. 2)

Dendrobaena ganglbaueri olympiaca Michaelsen, 1902: 47.

Dendorbaena byblica olympiaca: Szederjesi 2015: 145.

New data: HNHM/17015 6 ex., *No. 16.*

Table 1. List of collecting localities in Crete.

Number	Site description
1	Strovles, NW of the village, streamside with *Platanus* and olive trees, 35°22.491′N, 23°39.797′S, 392 m, 04.04.2015., leg. L. Dányi
2	Asfendiles, W of the village, rocky pasture with shrubs, 35°15.731′N, 23°43.710′S, 555 m, 03.04.2015., leg. L. Dányi
3	Kombanos, W of the village, group of springs and stream with *Platanus* and olive trees, 35°18.772′N, 23°47.586′S, 396 m, 03.04.2015., leg. L. Dányi
4	Seliniotikos Giros, at a temporary pond on the Omalos Plateau, pasture, 35°19.510′N, 23°53.473′S, 1060 m, 02.04.2015., leg. L. Dányi
5	Omalos, valley before the Samaria Gorge, pasture with *Acer* trees, 35°18.779′N, 23°54.924′S, 1194 m, 02.04.2015., leg. L. Dányi
6	Omalos, under the Kalergi Refugee, forest of *Qerqus coccifera*, *Q. aegiops* and *Acer*, 35°19.106′N, 23°55.242′S, 1229 m, 03.04.2015., leg. L. Dányi
7	Omalos, Omalos Plateau, E of the village, pasture with *Acer* trees, 35°19.739′N, 23°54.710′S, 1086 m, 02.04.2015., leg. L. Dányi
8	Theriso, Theriso Gorge, *Ceratonia siliqua* and *Platanus* forest along a dry streambed, 35°25.889′N, 23°59.408′S, 421 m, 02.04.2015., leg. L. Dányi
9	Garipa, Theriso Gorge, Platanus forest along a stream, 35°28.184′N, 23°59.251′S, 110 m, 02.04.2015., leg. L. Dányi
10	Piso Moni Preveli, Preveli Gorge, palm forest, 35°9.207′N, 24°28.419′S, 15 m, 01.04.201.5, leg. L. Dányi
11	Anogia, above the Nida Plateau, shrubland with Quercus coccifera and Acer, 35°12.350′N, 24°50.120′S, 1368 m, 05.04.2015., leg. L. Dányi, S. Simaiakis
12	Anogia, Nida Plateau, pasture, 35° 12.349′N, 24° 50.235′S, 1350 m, 05.04.2015., leg. L. Dányi, S. Simaiakis
13	Anogia, NE to the Nida Plateau, open forest of *Acer* and *Quercus coccifera*, 35°13.670′N, 24°52.710′S, 1424 m, 05.04.2015., leg. L. Dányi, S. Simaiakis
14	Spilia, SW of Agia Eirini church, gorge with stream and platan trees, 35°16.848′N, 25°9.891′S, 133 m, 27.03.2015., leg. L. Dányi, S. Simaiakis
15	Skalani, Karteros Gorge, streamshore and frigana, 35°16.662′N, 25°12.275′S, 71 m, 27.03.2015., leg. L. Dányi, S. Simaiakis
16	Platanias, Kofinas Peak, stony pasture with shrubs, 34°57.908′N, 25°5.612′S, 1080 m, 31.03.2015., leg. L. Dányi
17	Kaminaki, before the pass to Katofigi, pasture with *Quercus coccifera* and *Acer* sp., 35°7.880′N, 25°26.788′S, 1207 m, 28.03.2015., leg. L. Dányi
18	Ag. Konstantinos, NE of the village, open *Quercus coccifera* forest, 35°10.627′N, 25°30.517′S, 847 m, 28.03.2015., leg. L. Dányi
19	Katharon, before (NE of) the Plateau, very old *Quercus coccifera* forest, 35°9.200′N, 25°35.293′S, 1058 m, 29.03.2015, leg. L. Dányi
20	Kritsa, in direction to the Katharon Plateau, pasture with shrubs and a temporary pond, 35°9.472′N, 25°37.087′S, 788 m, 29.03.2015., leg. L. Dányi
21	Males, E of the village, machia with large pine trees, 35°4.824′N, 25°35.703′S, 586 m, 31.03.2015., leg. L. Dányi
22	Loutraki Kato Simis, at a gorge NW of the village, *Quercus coccifera* at the edge of an olive plantation, 35°1.501′N, 25°31.844′S, 415 m, 31.03.2015., leg. L. Dányi
23	Thripti, S of the village, very old pine forest, 35°4.928′N, 25°51.556′S, 786 m, 29.03.2015., leg. L. Dányi
24	Exo Mouliana, Richti Gorge, around the Rechtis Waterfall with *Platanus* trees, 35°11.114′N, 25°59.190′S, 141 m, 30.03.2015., leg. L. Dányi
25	Toplou, W of the village, dry, stony shrubland pasture, 35°13.215′N, 26°12.338′S, 157 m, 30.03.2015., leg. L. Dányi
26	Toplou, W of the village, small gorge with *Quercus coccifera* and *Ceratonia siliqua*, 35°13.250′N, 26°12.727′S, 160 m, 30.03.2015., leg. L. Dányi

Remark. New for the fauna of Crete.

***Dendrobaena hortensis* (Michaelsen, 1890)**

Allolobophora subrubicunda var. *hortensis* Michaelsen, 1890: 15.

Eisenia veneta var. *hibernica*: Cognetti 1906: 5.

Dendrobaena hortensis: Szederjesi 2015: 146.

New data: HNHM/17033 7 ex., *No. 15.* HNHM/17037 6 ex., *No. 14.* HNHM/17040 3 ex., *No. 9.*

Previous occurrences in Crete: Neapoli (Cognetti 1906), Ida Mts, Loutraki (Szederjesi 2015).

***Dendrobaena pantaleonis* (Chinaglia, 1913)**

Helodrilus (*Bimastus*) *pantaleonis* Chinaglia, 1913: 5.

Dendrobaena pantaleonis: Pavlíček & Csuzdi 2016: 11.

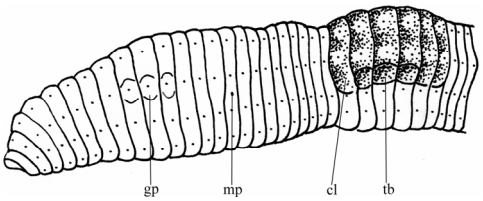

Figure 2. Ventrolateral view of the clitellar region of *Dendrobaena byblica olympiaca*. cl = clitellum, tb = tubercle, gp = genital papillae, mp = male pore.

New data: HNHM/17000 1 ex., *No. 3.* HNHM/17003 1 ex., *No. 1.* HNHM/17023 4 ex., *No. 8.* HNHM/17042 1 ex., *No. 9.*

Remark. This is the first record of *D. pantaleonis* from Crete.

***Dendrobaena veneta veneta* (Rosa, 1886)**

Allolobphora veneta Rosa, 1886: 674.

Eisenia veneta forma *typica*: Michaelsen 1902: 39.

?*Eisenia alpina* f. *typica*: Černosvitov 1934: 18.

Dendrobaena veneta veneta: Szederjesi & Csuzdi 2012a: 34.

Dendrobaena veneta: Szederjesi 2015: 147.

New data: HNHM/16988 8 ex, HNHM/16995 1 ex., *No. 13.* HNHM/16991 8 ex., *No. 11.* HNHM/16996 10 ex., *No. 12.* HNHM/17011 1 ex., *No. 22.* HNHM/17014 2 ex., *No. 16.* HNHM/17019 2 ex., No. 21. HNHM/17021 1 ex., *No. 7.* HNHM/17022 1 ex., *No. 8.* HNHM/17025 3 ex., *No. 6.* HNHM/17027 2 ex., *No. 26.* HNHM/17028 2 ex., *No. 25.* HNHM/17029 2 ex., *No. 18.* HNHM/17030 15 ex., *No. 17.* HNHM/17032 1 ex., *No. 15.* HNHM/17043 6 ex., HNHM/17044 6 ex., *No. 20.*

Previous occurrences in Crete: Dafnes (Michaelsen 1902), Psiloritis Mts? (Černosvitov 1934), Agii Deka, Ida Mts, Samaria, Pinakiano (Szederjesi 2015).

Remarks. Both the typical striped and the slightly red-pigmented specimens occured in our material.

Černosvitov (1934) recorded *Dendrobaena alpina* from Crete. He examined 10 specimens and observed some differences from those he studied earlier from Romania. The red-violet pigmentation, length (40-68 mm) and diameter (4-5 mm), the setal ratio, papillae on segment 11 *ab-cd*, the large male pore and the position of the clitellum (25-33) makes them very similar to our *D. veneta* specimens collected from Crete. He also noticed a slight variance in the position of the tubercles (30-31, ½32, 32) just like in case of our specimens (30-31, ½32). Unfortunately, he did not mention the position of the last hearts and the presence/absence of calciferous diverticula, thus we can not decide unequivocally whether his specimens were *D. alpina* or *D. veneta*.

***Eisenia ebneri* (Michaelsen, 1914)** (Fig. 3)

Helodrilus (*Eisenia*) *venetus ebneri* Michaelsen, 1914: 8-9.

Eisenia ebneri: Szederjesi & Csuzdi 2012a: 35.

New data: HNHM/16998 5 ex., *No. 2.* HNHM/17020 1 ex., *No. 7.* HNHM/17024 1 ex., *No. 6.*

Remark. *E. ebneri* is found solely in Greece and new for the fauna of Crete.

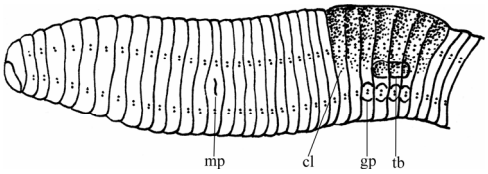

Figure 3. Ventrolateral view of the clitellar region of *Eisenia ebneri*. cl = clitellum, tb = tubercle, gp = genital papillae, mp = male pore.

***Eisenia fetida* (Savigny, 1826)**

Enterion fetidum Savigny, 1826: 182.

Eisenia fetida: Szederjesi & Csuzdi 2012a: 35.

New data: HNHM/17001 1 ex., *No. 3.*

Remark. This peregrine species hasn't been recorded so far from Crete.

***Eiseniella tetraedra* (Savigny, 1826)**

Enterion tetraedrum Savigny, 1826: 184.

Eiseniella tetraedra f. *typica*: Michaelsen 1902: 38; Černosvitov 1934: 17.

Eiseniella tetraedra (*typica*): Cognetti 1906: 3.

Eiseniella tetraedra mut. *intermedia*: Černosvitov 1934: 17.

Eiseniella tetraedra: Szederjesi 2015: 147.

New data: HNHM/16992 1 ex., *No. 11.* HNHM/17039 2 ex., *No. 24.*

Previous occurrences in Crete: Rethymno (Michaelsen 1902), Neapoli (Cognetti 1906), Knossos (Černosvitov 1934), Agii Deka, Agios Ioannis, Ida Mts, Sisarcha, Skafi (Szederjesi 2015).

***Lumbricus rubellus* Hoffmeister, 1843**

Lumbricus rubellus Hoffmeister, 1843: 187. Szederjesi 2015: 148.

New data: HNHM/17002 7 ex., *No. 1.*

Previous occurrences in Crete: Kakopetros (Szederjesi 2015).

***Murchieona minuscula* (Rosa, 1905)**

Allolobophora minuscula Rosa, 1905: 38.

Murchieona minuscula: Mršić 1991: 535 (for com-

plete synonymy).

New data: HNHM/17031 1 ex., *No. 19.*

Remark. New for the fauna of Crete.

Murchieona is a peculiar earthworm genus separated from *Allolobophora* by Gates (1978), based on the morphology of the calciferous glands and the nephridial bladders. Because of the high similarity, *M. muldali* has long been regarded as a synonym of *M. minuscula*, until Zicsi & Csuzdi (1999) reinstated this species on the basis of the position of the clitellum (26-32 *vs.* 27-33) and the different distributional patterns (Csuzdi & Pavlíček 2002).

***Octodrilus complanatus* (Dugès, 1828)**

Lumbricus complanatus Dugès, 1828: 289.

Octolasium complanatum: Michaelsen 1902: 51. Cognetti 1906: 17.

Octodrilus complanatus: Szederjesi 2015: 148.

New data: HNHM/16993 1 ex., *No. 13.* HNHM/16999 3 ex., *No. 3.* HNHM/17004 1 ex., *No. 5.* HNHM/17009 1 ex., *No. 10.* HNHM/17010 1 ex., *No. 22.* HNHM/17012 1 ex., *No. 16.* HNHM/17017 1 ex., *No. 21.* HNHM/17045 1 ex., *No. 23.*

Previous occurrences in Crete: Omalos, Rethymno, Chania, Dafnes, Aselakia, Askifou Plateau, Tsikalaria, Vizari (Michaelsen 1902), Kristallenia (Cognetti 1906), Axos, Agii Deka, Sisarcha, Moni Veni, Apostoli, Gouledianа, Katharo (Szederjesi 2015).

Family Acanthodrilidae Claus, 1880

***Microscolex dubius* (Fletcher, 1887)**

Eudrilus dubius Fletcher, 1887: 378.

Microscolex dubius: Szederjesi 2015: 149.

New data: HNHM/AF5645 2 ex., *No. 10.* HNHM/AF5646 4 ex., *No. 9.* HNHM/AF5647 3 ex., *No. 3.*

Previous occurrences in Crete: Krasi, Sougia (Szederjesi 2015).

Discussion

With the new data, the earthworm fauna of Crete comprises 20 species, while the presence of two species is in question (Table 2). Among them, 8-10 species (38.1-47.6%) are introduced peregrine (Fig. 4). *A. chlorotica chlorotica* and *Aporrectodea rosea* are probably the most widespread earthworm species throughout in the world. *Eis. tetraedra* is also widely introduced all over the world (Csuzdi & Zicsi 2003) and, as a limicolous species it prefers damp habitats and is usually found on the banks of streams and riversides. There is no specific information about the presence of *Ap. caliginosa caliginosa* in Crete, but in any event it seems that the subspecies *Ap. caliginosa trapezoides* is more common in the Mediterranean region (see Remarks and Fernández et al. 2011). *E. fetida* is probably originated from the Caucasus and the forest-steppe zone of Russia (Perel 1997); however, as it is now used for vermicomposting, it has become widely introduced in Europe and North America (Csuzdi & Zicsi 2003). The situation is similar with *D. hortensis*: its origin is unknown, but as a manure worm it is now found all over in Europe, mainly in composts. *L. rubellus* is also widespread extratropically, prefering moist habitats with rich organic material (Csuzdi & Zicsi 2003). *M. dubius* – the only species in Crete that belongs to the family Acanthodrilidae – is probably of South American origin, but now it is found in warmer regions all over the world (Blakemore 2008).

Among the native species, three show Circum-Mediterranean distribution. From these presumably the taxonomically vague *D. byblica* possesses the widest range. This species has similar habitat preference to *Eis. tetraedra*. The large-bodied anecic *Oc. complanatus* is present from North Africa and Spain through the countries of southern Europe and Cyprus to Turkey and the Levantine region (Pavlíček & Csuzdi 2016). The finding of this species on the sandy shores of Greece (Szederjesi & Csuzdi 2012a) implies a certain degree of salt tolerance. If this suggestion is correct, not only in the case of the specimens but also in the case of their cocoons, it can well explain the wide range of *Oc. complanatus* throughout the Mediterranean, however, further investigations are needed. *M. minuscula* is known from Italy, Croatia, continental Greece, Israel (Csuzdi & Pavlíček 2002), Turkey (Pavlíček et al. 2009), Cyprus (Pavlíček & Csuzdi 2016) and now from Crete. This tiny species (20-22 mm) is usually found stucked into small soil particles; as a result, it is clearly possible that human activity can also take part in its distribution.

Two species appear to be narrower Balkanic endemisms. Both *D. byblica olympiaca* and *E. ebneri* are known only from the southern part of continental Greece and Crete, *D. byblica olympiaca* was also found in Naxos (Szederjesi 2015).

The Atlanto-Mediterranean *Ap. georgii* has a wide range that covers the whole of Southern Europe, but having been introduced it can be found in other parts of the world too (Csuzdi & Zicsi 2003). The Trans-Aegean distribution type is

Table 2. List of earthworm species known from Crete, their distribution and ecological types.

Species	Distribution type	Ecological category
Allolobophora chlorotica chlorotica (Savigny, 1826)	Peregrine	Endogeic
Aporrectodea caliginosa trapezoides (Dugès, 1828)	Peregrine	Endogeic
Aporrectodea georgii (Michaelsen, 1890)	Atlanto-Mediterranean	Endogeic
Aporrectodea jassyensis (Michaelsen, 1891)	Trans-Aegean	Endogeic
Aporrectodea rosea (Savigny, 1826)	Peregrine	Endogeic
Dendrobaena byblica byblica (Rosa, 1893)	Circum-Mediterranean	Endogeic
Dendrobaena byblica olympiaca (Michaelsen, 1902)	Balkanic endemism	Endogeic
Dendrobaena hortensis (Michaelsen, 1890)	Peregrine	Epigeic
Dendrobaena pantaleonis (Chinaglia, 1913)	South Alpine-East Mediterranean	Endogeic
Dendrobaena veneta veneta (Rosa, 1886)	Caucasian-East Mediterranean/Peregrine	Epigeic
Eisenia ebneri (Michaelsen, 1914)	Balkanic endemism	Endogeic
Eisenia fetida (Savigny, 1826)	Peregrine	Epigeic
Eiseniella tetraedra (Savigny, 1826)	Peregrine	Endogeic
Helodrilus patriarchalis (Rosa, 1893)	Caucasian-East Mediterranean	Endogeic
Lumbricus rubellus Hoffmeister, 1843	Peregrine	Epigeic
Murchieona minuscula (Rosa, 1905)	Circum-Mediterranean	Endogeic
Octodrilus complanatus (Dugès, 1828)	Circum-Mediterranean	Anecic
Microscloex dubius (Fletcher, 1887)	Peregrine	Endogeic
?*Aporrectodea caliginosa caliginosa* (Savigny, 1826)	Peregrine	Endogeic
?*Dendrobaena alpina alpina* (Rosa, 1894)	Balkanic-Alpine	Endogeic

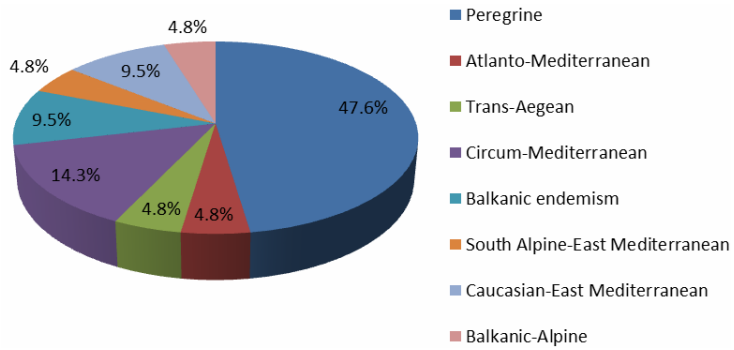

Figure 4. Zoogeographical composition of the Cretan earthworm fauna.

represented with one species, *Aporrectodea jassyensis* (Michaelsen, 1891), which is known from Italy through Central Europe and the Balkans to Turkey, Cyprus, Levant and North Africa (Pavlíček & Csuzdi 2016). This type of distribution is probably connected with the complex tectonic history of the East Mediterranean (Csuzdi & Zicsi 2003). The South Alpine-East Mediterranean *D. pantaleonis* has a narrower range from Corsica, Italy, Albania, Greece, Turkey (Szederjesi & Csuzdi 2012b) and Cyprus (Michalis 1993), presumably originated from Southern Europe. Two species show Caucasian-East Mediterranean distribution, which are probably originated from the Caucasus and spread to Turkey, the Levantine region, Cyprus (Pavlíček & Csuzdi 2016) and to Crete. One of them is the epigean *D. veneta*. The stripe-pigmented form of this species is used for vermicomposting and therefore introduced worldwide. The other species is the limicolous *Helodrilus patriarchalis* (Rosa, 1893), commonly found on stream banks and swamps. The presence of the Balkanic-Alpine *Dendrobaena alpina alpina* (Rosa, 1884) in Crete is in question. This species occurs in the Alps, the Carpathian Arcs and in the Balkans (Pop et al. 2007), it reaches its southernmost distribution in Drama and Xanthi County, Northern Greece (Szederjesi & Csuzdi 2012a).Crete covers an area of 8,336 km^2 and is similar in size to Corsica (8,680 km^2) and Cyprus (9,251 km^2); however, its tectonic history and zoogeographic relationships place it closer to the East-Mediterranean island of Cyprus

than to the West-Mediterranean Corsica with its Franco-Iberian zoogeographic influences (Csuzdi et al. 2011). Comparing Cretan earthworm fauna with that of Cyprus, Szederjesi et al. (2016) found a smaller ratio of peregrine species, ca. 38% of the 21 species known from the latter island. Furthermore, in the fauna of Cyprus clear Anatolian and Levantine affinities were observed with the presence of such species as *Dendrobaena pentheri* (Rosa, 1905) and *Dendrobaena semitica* (Rosa, 1893), which are missing from the fauna of Crete. This phenomenon probably originated in the Messinian Salinity Crisis period (5.96-5.33 my) when the island of Cyprus was presumably connected with the Levant through three, now submerged, land bridges (Pavlíček & Csuzdi 2008). In this period Crete was isolated from the east (Poulakakis et al. 2014) but probably had connections with the Peloponnese, and the two Balkanic endemic species were able to reach the island this way.

Though both expeditions focused on taking samples from various habitat types and different parts of Crete, number of species present on the island still appears to be low. Nonetheless, we have to take into account that the period of earthworm activity in this region, similar to that of Cyprus (Pavlíček & Csuzdi 2006), is limited by the soil humidity that is only appropriate in winter and early spring. Therefore collecting during the right period of the year may well result in recording more occurrence of species from Crete.

Acknowledgements. The research was supported by the Hungarian Scientific Research Fund (OTKA K100369). My thanks are due to Csaba Csuzdi (Eszterházy Károly College, Eger) for the useful comments and to Helmut Sattmann (Naturhistorisches Museum Wien) for giving possibility to visit the earthworm collection of the Natural History Museum, Vienna. Special thanks to László Dányi (Hungarian Natural History Museum, Budapest) and Stylianos Simaiakis (Natural History Museum of Crete, Heraklion) for the valuable material collected.

References

Blakemore, R.B. (2008): Cosmopolitan Earthworms – An Eco-Taxonomic Guide to the Species (3rd Edition). VermEcology, Yokohama, Japan.

Chinaglia, L. (1913): Escursioni zoologiche del Dr. E. Festa. Lumbricidae. Bollettino dei Musei di zoologia ed anatomia comparata della R. Università di Torino 28(667): 1-6.

Cognetti, L. (1906): Nuovi dati sui Lumbricidi dell'Europa orientale. Bollettino dei Musei di zoologia ed anatomia comparata della R. Università di Torino 21(257): 1-18.

Csuzdi, Cs., Pavlíček, T. (2002): *Murchieona minuscula* (Rosa, 1906), a newly recorded earthworm from Israel, and distribution of the genera *Dendrobaena* and *Bimastos* in Israel (Oligochaeta, Lumbricidae). Zoology in the Middle East 25: 105-114..

Csuzdi, Cs., Zicsi, A. (2003): Earthworms of Hungary (Annelida: Oligochaeta: Lumbricidae). In: Csuzdi, Cs., Mahunka, S. (eds.), Pedozoologica Hungarica 1. Hungarian Natural History Muesum, Budapest.

Csuzdi, Cs., Pop, V.V., Pop, A.A. (2011): The earthworm fauna of the Carpathian Basin with new records and description of three new species (Oligochaeta: Lumbricidae). Zoologischer Anzeiger 250: 2-18.

Černosvitov, L. (1934): Sur les Oligochètes terricoles de Crète. Sbornik Zoologického Oddeleni Narodniho Musea v Praze 1(4): 17-20.

Dugès, A. (1828): Recherche sur la circulation, la respiration, et la reproduction des Annélides sétigéres abranches. Annales des Sciences Naturelles Paris 15: 284-336.

Fernández, R., Almodóvar, A., Novo, M., Gutiérrez, M., Díaz Cosín, D. (2011): A vargant clone in a peregrine species: Phylogeography, high clonal diversity and geographical distribution in the earthworm *Aporrectodea trapezoides* (Dugès, 1828). Soil Biology & Biochemistry 43: 2085-2093.

Fletcher, J.J. (1887): Notes on Australian earthworms. Part III. Proceedings of the Linnean Society of New South Wales 2(2): 375-402..

Gates, G.E. (1978): The earthworm genus *Lumbricus* in North-America. Megadrilogica 3(6): 81-116.

Hoffmeister, W. (1843): Beitrag zur Kenntnis deutcher Landanneliden. Archiv für Naturgeschichte 91: 183-198.

Michaelsen, W. (1890): Die Lumbriciden Norddeutschlands. Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten 7: 1-19.

Michaelsen, W. (1902): Neue Oligochaeten und neue Fundorte altbekannter. Mitteilungen aus dem Naturhistorischen Museum in Hamburg 19: 3-53.

Michaelsen, W. (1914): Ein neuer Regenwurm aus Griechenland. Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien 8: 8-9.

Michalis, K. (1993): Contribution to the Study of the Oligochaeta fauna of Cyprus. Acta Zoologica Cracoviensia 36: 23-28**.**

Mršić, N. (1991): Monograph on earthworms (Lumbricidae) of the Balkans I-II. Slovenska Akademija Znanosti in Umetnosti, Zazred za Naravoslovne Vede, Ljubljana.

Pavlíček, T., Csuzdi, Cs. (2006): Species richness and zoogeographic affinities of earthworms in Cyprus. European Journal of Soil Biology 42: S111-S116.

Pavlíček, T., Csuzdi, Cs. (2006): Does the autochthonous earthworm fauna emigrate from the Levant to Cyprus? pp.189-200. In: Pavlíček, T., Cardet, P. (eds.), Advances in Earthworm Taxonomy III (Annelida: Oligochaeta). Nicosia, En Tipis Voula Kokkinou Ltd.

Pavlíček, T., Csuzdi, C. (2016): Chapter 23: Clitellata: Oligochaeta: Earthworms. pp.587-599. In. Sparrow, D.J., John, E. (eds): An Introduction to the Wildlife of Cyprus. Terra Cypria, Limassol.

Pavlíček, T., Csuzdi, Cs., Coşkun, Y. (2009): First earthworm records in Mesopotamia (Oligochaeta). Zoology in the Middle East 48(1): 119-120.

Pop, V.V., Pop, A.A., Csuzdi, Cs. (2007) An updated viewpoint on the earthworm communities with the *Dendrobaena alpina* species group (Oligochaeta, Lumbricidae) from the South-Eastern Carpathians. European Journal of Soil Biology 43: S53-S56.

Perel, T.S. (1997): The Earthworms of the Fauna of Russia. Nauka, Moscow.

Poulakakis, N., Kapli, P., Lymberakis, P., Trichas, A., Vardinoyiannis, K., Sfenthourakis, S., Mylonas, M. (2014): A review of phylogeographic analyses of animal taxa from the Aegean and surrounding regions. Journal of Zoological Systematics and Evolutionary Research 53(1): 18-32.

Raw, F. (1959): Estimating earthworm population by using formalin. Nature 184: 1661-1662.

Rosa, D. (1886): Note sui lombrici del Veneto. Atti del Reale Istituto Veneto di Scienze 4: 673-687.

Rosa, D. (1893): Viaggio del Dr. E. Festa in Palestina, nel Libano e regioni vicine. – II. Lumbricidi. Bollettino dei Musei di zoologia ed anatomia comparata della R. Università di Torino 8(160): 1-14.

Rosa, D. (1905): Terricolen. In: Ergebnisse einer Naturwissenschaftlichen Reise zum Erdschias Dag. Annalen des K.K. Naturhistorischen Hofmuseums Wien 20: 104-106.

Savigny, J.C. (1826): In Cuvier, G.: Analyse des Travaux de l'Académie royale des Sciences, pendant l'année 1821, partie physique. Mémoires de l'Académie des Sciences de l'Institut de France Paris 5: 176-184.

Steininger, F.F., Rögl, F. (1984): Paleogeography and palinspastic reconstruction of the Neogene of the Mediterranean and Paratethys. In: Dixon, J.E., Robertson, A.H.F. (eds.), The Geological Evolution of Eastern Mediterranean. Blackwell Scientific, Oxford.

Szederjesi, T. (2015): New earthworm records from various parts of Greece (Oligochaeta: Lumbricidae, Acanthodrilidae, Megacolecidae, Ocnerodrilidae). Opuscula Zoolica Budapest 46(2): 143-152.

Szederjesi, T., Csuzdi, Cs. (2012a): New and little known earthworm species from Greece (Oligochaeta: Lumbricidae, Acanthodrilidae). Zootaxa 3304: 25-42.

Szederjesi, T., Csuzdi, Cs. (2012b): New earthworm species and records from Albania (Oligochaeta, Lumbricidae). Acta Zoologica Academiae Scientiarum Hungaricae 58(3): 259-274.

Szederjesi, T., Pop, V.V., Csuzdi, Cs. (2014): New and little known earthworm species from peripheral areas of the Romanian Carpathians (Oligochaeta, Lumbricidae). Acta Zoologica Academiae Scientiarum Hungaricae 60(2): 85-107.

Szederjesi, T., Pavlíček, T., Csuzdi, Cs. (2016): Description of the first endemic earthworm species from Cyprus (Oligochaeta: Lumbricidae). Zoology in the Middle East 62(2): 158-163.

Zicsi, A., Pop, V.V. (1984): Neue Regenwürmer aus Rumänien (Oligochaeta: Lumbricidae). Acta Zoologica Academiae Scientiarum Hungaricae 30: 241-248.

Zicsi, A., Csuzdi, Cs. (1999): Further contribution to the earthworm fauna (Oligochaeta: Lumbricidae) of France, with description of five new species and one subspecies. Revue Suisse de Zoologie 106: 983-1003.