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Earthworms from northern parts of Sistan and Balouchestan Province, Iran (Oligochaeta, Lumbricidae)

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In this study, earthworms were collected from the wetlands of northern parts of Sistan and Balouchestan Province at 17 stations. The following nine species were identified: *Aporrectodea caliginosa* (Savigny, 1826), *Ap. jassyensis* (Michaelsen, 1891), *Ap. longa* (Ude, 1885), *Ap. rosea* (Savigny, 1826), *Ap. trapezoides* (Dugès, 1828), *Bimastos parvus* (Eisen, 1874), *Eisenia andrei/fetida* complex, *E. omranii* Latif, Malek and Csuzdi, 2017, and *Eiseniella tetraedra* (Savigny, 1826). All of the recorded species are new to the east of Iran. The most frequent species were *Ap. rosea* and *Ap. caliginosa*; and the rarest one was *E. andrei/fetida*. Length and total earthworm segments of each species were compared between specimens of the studied area and previous known values from Elburz (north of Iran) and/or Zagros (west of Iran) regions.

Key words: *Earthworm, Lumbricidae, New record, Sistan and Balouchestan, Iran.*

INTRODUCTION

Previous faunistic studies of earthworms in Iran, mainly focused on the northern and the western parts of the country, and as a result, several data were published (Latif *et al*., 2017). So far, 28 species belonging to three families were reported, namely, Lumbricidae (*Aporrectodea caliginosa* (Savigny, 1826), *Ap. jassyensis* (Michaelsen, 1891), *Ap. longa* (Ude, 1885), *Ap. rosea* (Savigny, 1826), *Ap. trapezoides* (Duges, 1828), *Bimastos parvus* (Eisen, 1874), *Dendrobaena byblica* (Rosa, 1893), *D. hortensis* (Michaelsen, 1890), *D. octaedra* (Savigny, 1826), *D. orientalis* Cernosvitov, 1940, *D. pentheri* (Rosa, 1905), *D. semitica* (Rosa, 1893), *D. veneta* (Rosa, 1886), *Dendrodrilus rubidus* (Savigny, 1826), *Eisenia andrei* Bouché, 1972, *E. fetida* (Savigny, 1826), *E. malekae* Szederjesi, Latif & Csuzdi, 2014, *E. omranii* Latif, Malek & Csuzdi, 2017, *Eiseniella tetraedra* (Savigny, 1826), *Healyella syriaca* (Rosa, 1893), *Helodrilus patriarchalis* (Rosa, 1893), *Octolasion lacteum* (Orley, 1881), *Perelia kaznakovi* (Michaelsen, 1910), and *P. persiana* (Michaelsen, 1900)); Acanthodrilidae (*Dichogaster bolaui* (Michaelsen, 1891), *Microscolex phosphoreus* (Dugès, 1837), and *M. dubius* (Fletcher, 1887)); and Megascolecidae (*Amynthas corticis* (Kinberg, 1867)) (Omrani, 1973; Latif *et al*., 2009; Ezzatpanah *et al*., 2010; Mirmonsef *et al*., 2011; Farhadi *et al*., 2013; Latif *et al*., 2017). Our knowledge on earthworms in Iran are still inadequate and much remains to be learned of earthworm taxonomy in the country especially

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because the study of earthworms has been neglected in many regions in the east of Iran and no information is available about the earthworm fauna in this region. The aim of the present study is to determine the earthworm fauna, habitat, and distribution pattern in northern parts of Sistan and Balouchestan Province.

MATERIAL AND METHODS

In this study, earthworm specimens were collected from northern parts of Sistan and Balouchestan Province. This area in southeastern of Iran is the second largest province of the country which covers a land area of 187,502 km² (more than 11% of total area of Iran) (Sbportal, 2018). This Province is located in the Asian desert belt, with a semi-arid climate with low precipitation. The main source of water is the Hilmand River (Darvishzadeh, 1991). The average temperature in July is about 45°C while in January it descends to 7.5°C (Sobhkhyzi *et al.*, 2006). The strong winds, sometimes reaching 150 km/h, have an important impact on the environmental conditions. The wind of 120 days (or the wind of lavar) that blows from north-west to the south-east during summer, led to a serious erosion of the land (Jux & Kempf, 1983).

In the present study, earthworms were collected by digging up the soil blocks and hand sorting worms at 17 stations in June 2018 (Table 1 & Fig. 1). The size of blocks was 25×25×25 cm. Five blocks were randomly dug at each station. Collected specimens were anaesthetized in 15% and fixed in 80% ethanol, respectively. Specimens were deposited in the Zoological Museum of Bu-Ali Sina University (ZMBASU). The identification of adult earthworms conducted mainly based on position and shape of clitellum, setae, and internal organs such as nephridial bladders; according to Csuzdi & Zicsi (2003), Sims & Gerard (1999), and Perel (1979).

After species identification, data of each block and station was extracted. Length and total earthworm segments were recorded for adult specimens. Statistical analyses of data were performed using SPSS statistical software package (Version 22). The values of density were transformed to log(x) to normalize them before analysis. Differences between species abundance were analyzed using Chi-square test. One-way analysis of variance (ANOVA) was used to compare relative abundance and density among species and occurrence situations of species; and Duncan mean comparisons were utilized to produce pairwise comparison of the different situations. Statistical significance was assumed at $p<0.05$. Length and total earthworm segments of each species were compared between present specimens and previous known values from Elburz (north of Iran) and/or Zagros (west of Iran) regions.

Abbreviations were used throughout the text as follows; *Ac*: *Aporrectodea caliginosa*, *At*: *Ap. trapezoides*, *Aj*: *Ap. jassyensis*, *Ar*: *Ap. rosea*, *Al*: *Ap. longa*, *Bp*: *Bimastos parvus*, *Eo*: *Eisenia omranii*, *Ea*: *E. andrei/fetida*, *Et*: *Eiseniella tetraedra*, L: Lonely, Co: Co-occurrence, NS: Not Significant, and S: Significant.

RESULTS

In this study 301 specimens were collected, which identified as nine species, namely, *Aporrectodea caliginosa*, *Ap. jassyensis, Ap. longa*, *Ap. rosea*, *Ap. trapezoides*, *Bimastos parvus*, *Eisenia andrei/fetida*, *E. omranii*, and *Eiseniella tetraedra*. These species, all belong to the family Lumbricidae. Seven species are peregrine, one endemic, and one circum-mediterranean (Table 2).

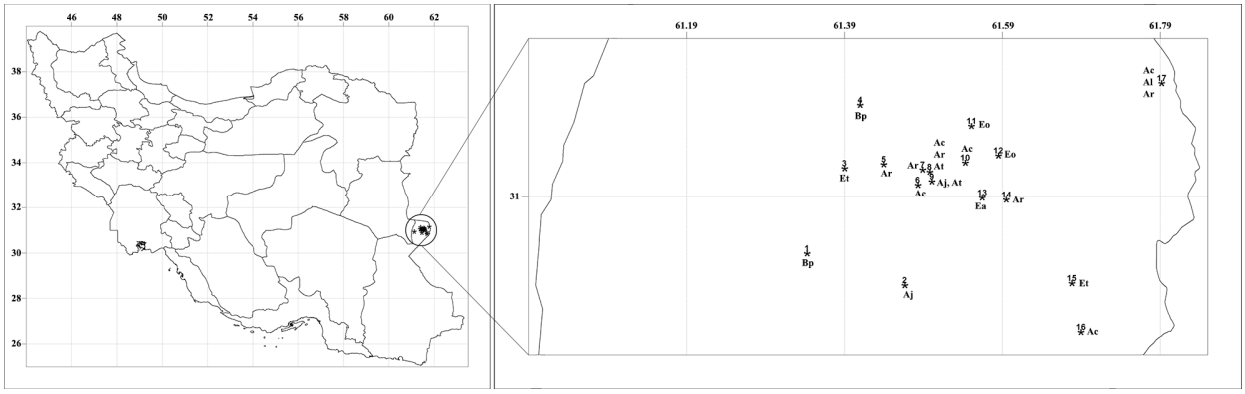

FIGURE 1. Location of sampling sites and collected species of earthworms in each station in studied area.

TABLE 1. List and geographic coordinates of sampling sites.

Number of Sampling Site	Locality Name	Latitude (N)	Longitude (E)
1	Hamoon	30° 55' 41"	61° 20' 34"
2	Mohammad-Abad	30° 53' 16"	61° 27' 59"
3	Shahrak Golkhani	31° 02' 10"	61° 23' 25"
4	Adimi	31° 06' 58"	61° 24' 36"
5	Qaem-Abad	31° 02' 28"	61° 26' 24"
6	Zabol 12	31° 00' 21"	61° 28' 59"
7	University of Zabol	31° 02' 04"	61° 29' 21"
8	Zabol 11	31° 01' 53"	61° 29' 53"
9	Zabol 13	31° 01' 10"	61° 30' 03"
10	Zabol (Mohammad-Abad)	31° 02' 35"	61° 32' 35"
11	Heidar-Abad	31° 05' 22"	61° 33' 03"
12	Emamieh	31° 03' 08"	61° 35' 06"
13	Zhalaei	30° 59' 55"	61° 33' 52"
14	Tapeh-Duz	30° 59' 46"	61° 35' 42"
15	Zahak	30° 53' 25"	61° 40' 41"
16	Chah-Nimeh	30° 49' 43"	61° 41' 22"
17	Doustmohammad	31° 08' 37"	61° 47' 30"

TABLE 2. Abundance and density of identified earthworm species from northern parts of Sistan and Balouchestan Province.

Species	Chorotype	Habitat	Presence Frequency (%)	Frequency of Lonely Occurrence (%)	Frequency of Co-Occurrence with Other Species (%)	Abundance	Relative Abundance (%)	Mean Density ±SE (No m^{-2})
Aporrectodea caliginosa	Peregrine	Grassland	5 of 17 stations (29.41)	60	Al, Ar (20); Ar, At (20)	98	32.56	18.45±3.87
Ap. trapezoides	Peregrine	Grassland	2 of 17 stations (11.76)	0	Ac, Ar (50); Aj (50)	21	6.98	3.95±1.31
Ap. rosea	Peregrine	Grassland	5 of 17 stations (29.41)	60	Ac, Al (20); Ac, At (20)	105	34.88	19.76±3.95
Ap. jassyensis	Circum-Mediterranean	woody areas	2 of 17 stations (11.76)	50	At (50)	13	4.32	2.45±0.87
Ap. Longa	Peregrine	woody areas	1 of 17 stations (5.88)	0	Ac, Ar (100)	6	1.99	1.13±0.52
Bimastos parvus	Peregrine	Damp habitat	2 of 17 stations (11.76)	100	- (0)	16	5.32	3.01±0.98
Eisenia andrei/fetida	Peregrine	woody areas	1 of 17 stations (5.88)	100	- (0)	4	1.33	0.75±0.75
E. omranii	Endemic	woody areas	2 of 17 stations (11.76)	100	- (0)	12	3.99	2.26±0.93
Eiseniella tetraedra	Peregrine	Damp habitat	2 of 17 stations (11.76)	100	- (0)	26	8.64	4.89±1.61

Systematics

Family Lumbricidae (Rafinesque-Schmaltz, 1815)

***Aporrectodea caliginosa* (Savigny, 1826)**

Aporrectodea caliginosa: Csuzdi & Zicsi 2003: 75 (for complete synonymy).

Material examined: (ZMBASU 1), [Chah-Nimeh (30° 49' 43", 61° 41' 22")]; (ZMBASU 2), [Doustmohammad (31° 08' 37", 61° 47' 30")]; (ZMBASU 3), [Zabol (Mohammad-Abad) (31° 02' 35", 61° 32' 35")]; (ZMBASU 4), [Zabol 11 (31° 01' 53", 61° 29' 53")]; and (ZMBASU 5), [Zabol 12 (31° 00' 21", 61° 28' 59")]; [May 2018]; leg. [Naser Sanchooli].

Ecology: endogeic.

Remarks: Clitellum and tubercles respectively extend on segments 27-34, 31-33. Tubercula bipartite, pigmentation absent, whitish-grey colour. Some of them have extended prostomium into a proboscis. 110-117 segments.

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

Aporrectodea trapezoides: Blakemore 2008: 503-506 (for complete synonymy).

Material examined: (ZMBASU 6), [Zabol 11 (31° 01' 53", 61° 29' 53")]; and (ZMBASU 7), [Zabol 13 (31° 01' 10", 61° 30' 03")]; [May 2018]; leg. [Naser Sanchooli].

Ecology: endogeic.
Remarks: Clitellum and tubercles respectively on segments 27-34, 31-33. Tubercles band-shaped, dorsal surface light to dark brown. 184-190 segments.

***Aporrectodea jassyensis* (Michaelsen, 1891)**
Aporrectodea jassyensis: Csuzdi & Zicsi 2003: 87 (for complete synonymy).
Material examined: (ZMBASU 8), [Mohammad-Abad (30° 53' 16", 61° 27' 59")]; and (ZMBASU 9), [Zabol 13 (31° 01' 10", 61° 30' 03")]; [May 2018]; leg. [Naser Sanchooli].
Ecology: endogeic
Remarks: Clitellum extends on 29-35, tubercles on 1/n 31, 32-34, pale color. 100-120 segments.

***Aporrectodea rosea* (Savigny, 1826)**
Aporrectodea rosea: Csuzdi & Zicsi 2003: 92 (for complete synonymy).
Material examined: (ZMBASU 10), [Doustmohammad (31° 08' 37", 61° 47' 30")]; (ZMBASU 11), [Qaem-Abad (31° 02' 28", 61° 26' 24")]; (ZMBASU 12), [Tapeh-Duz (30° 59' 46", 61° 35' 42")]; (ZMBASU 13), [University of Zabol (31° 02' 04", 61° 29' 21")]; and (ZMBASU 14), [Zabol 11 (31° 01' 53", 61° 29' 53")]; [May 2018]; leg. [Naser Sanchooli].
Ecology: endogeic
Remarks: Clitellum on segments (24)25-32, tubercles on segments 29-31. Dorsal pores are readily visible, especially on the clitellum. 115-132 segments.

***Aporrectodea longa* (Ude, 1885)**
Aporrectodea longa: Csuzdi & Zicsi 2003: 89 (for complete synonymy).
Material examined: (ZMBASU 15), [Doustmohammad (31° 08' 37", 61° 47' 30")]; [May 2018]; leg. [Naser Sanchooli].
Ecology: endo-anecic
Remarks: Clitellum extends on segments 27-35, tubercles on 1/n 31, 32-34, dark brown color. 210–220 segments.

***Bimastos parvus* (Eisen, 1874)**
Bimastos parvus: Blakemore 2008: 537 (for complete synonymy).
Material examined: (ZMBASU 16), [Adimi (31° 06' 58", 61° 24' 36")]; (ZMBASU 17), [Hamoon (30° 55' 41", 61° 20' 34")]; [May 2018]; leg. [Naser Sanchooli].
Ecology: epigeic
Remarks: Clitellum extends on segments 24-31, tubercles absent, color usually reddish, sometimes pale and at two end of body appears rosy. 63–70 segments.

***Eisenia omranii* Latif, Malek & Csuzdi, 2017**
Material examined: (ZMBASU 18), [Emamieh (31° 03' 08", 61° 35' 06")]; (ZMBASU 19), [Heidar-Abad (31° 05' 22", 61° 33' 03")]; [May 2018]; leg. [Naser Sanchooli].
Ecology: endo-epigeic
Remarks: Clitellum extends on 25(26)-34, tubercles on 30–1/n34, colour dark brown on the dorsum and somewhat lighter on the ventrum. 92-96 segments.

***Eisenia andrei/fetida* complex**
Eisenia andrei/fetida: Dominguez *et al.* 2005: for complete synonymy.
Material examined: (ZMBASU 20), [Zhalaei (30° 59' 55", 61° 33' 52")]; [May 2018]; leg. [Naser Sanchooli].
Ecology: epigeic

Remarks: Clitellum on segment 26-32, tubercles on segments 28-31, dorsal surface brown-red and pigmentation often absent from furrows. 105-110 segments.

***Eiseniella tetraedra* (Savigny, 1826)**
Eiseniella tetraedra: Csuzdi & Zicsi 2003: 153 (for complete synonymy).
Material examined: (ZMBASU 21), [Shahrak Golkhani (31° 02' 10", 61° 23' 25")]; (ZMBASU 22), [Zahak (30° 53' 25", 61° 40' 41")]; [May 2018]; leg. [Naser Sanchooli].
Ecology: epigeic
Remarks: Clitellum on segments 23-26, tubercles on segments 24-25. Tail with characteristic tetrahedral shape. 80–85 segments.

DISSCUSSION

According to the previous studies in Iran, 28 species, belonging to 13 genera and three families of earthworms have been reported. The highest biodiversity in Iran is recorded in the west of Iran by Latif *et al.* (2017). In spite of the some exploratory works in Iran, the eastern part of the country hasn't been studied so far and results of this study represent new records for the earthworm fauna of the region. Earthworm fauna of studied region is comprised of four genera; namely, *Aporrectodea*, *Bimastos*, *Eisenia* and *Eiseniella*. Most species in this region are cosmopolitan (*Ap. caliginosa, Ap. trapezoides*, *Ap. rosea, Ap. longa, B. parvus*, *E. andrei/fetida* and *Eis. tetraedra*) and two species are native (*Ap. jassyensis* and *E. omranii*). It is surprising that some common species, like species of genus *Dendrobaena* which are widely distributed in the other parts of Iran (Latif *et al.*, 2009), were not recorded from this area. Genus *Dendrobaena* constitutes the predominant component of earthworms in Elburz region (Latif *et al.*, 2009); while genus *Aporrectodea* is the important component of earthworm fauna in northern parts of Sistan and Balouchestan Province.

Ap. caliginosa and *Ap. rosea* were the most abundant species which were found in five stations and had the greatest density; the other seven species had lesser abundance and density, and found in one/two stations. The rarest species was *E. andrei/fetida* which was found only in one station. Coexistence was found among five species while four others were found separately in one station (Table 2). Statistical analyses showed significance differences among species abundance (Fig. 2) and density (Fig. 3).

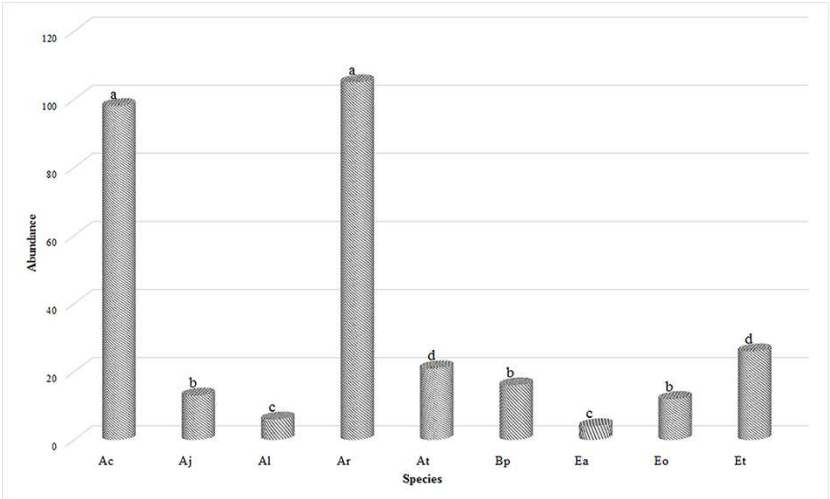

FIGURE 2. Comparison of species abundance. Bars with the different letters are significantly different according to Chi-square test.

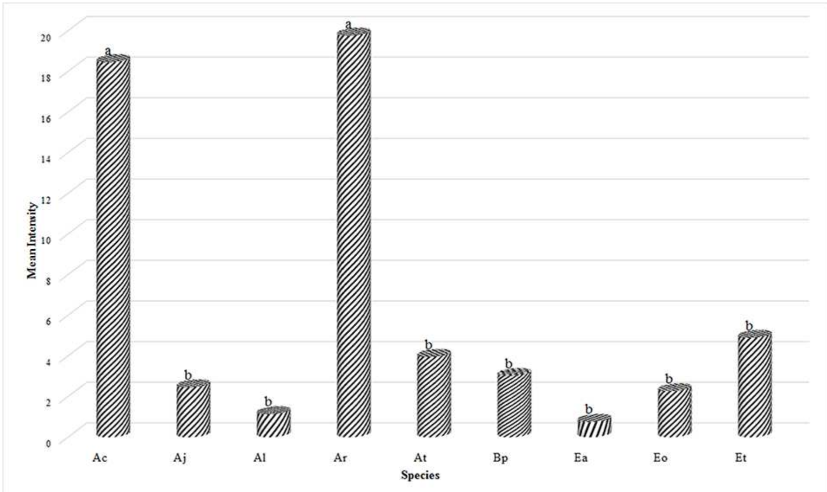

FIGURE 3. Comparison of species density. Bars with the different letters are significantly different according to Duncan test.

Ap. caliginosa and *Ap. rosea* were approximately similar in abundance and density. They co-occurred in two stations and occurred separately in three stations (Table 2). These species had similar abundances and densities in coexistence and lonely situations with each other but abundance and density in lonely situation were significantly higher than coexistence situation, for each species; also, abundance and density of each species in lonely stations were significantly higher than total abundance and density of two species in common stations (Table 3).

TABLE 3. Comparison of abundance and density of *Ap. caliginosa* and *Ap. rosea* in co-occurrence and lonely situations.

Species	Type of Occurrence	Abundance	Relative Abundance (%)	Mean Density ±SE (No m^{-2})
Ap. caliginosa	Lonely	70	100	74.67±9.19
	Co-occurrence	28	38.37	44.80±9.18
Ap. rosea	Lonely	78	100	83.20±9.13
	Co-occurrence	27	36.99	43.20±7.18
Differences		L.Ac and L.Ar (NS) Co.Ac and Co.Ar (NS) L.Ac > Co.Ac (S) L.Ar > Co.Ar (S) Co(Ac+Ar) < L.Ac (NS) Co(Ac+Ar) < L.Ar (S)	L.Ac and L.Ar (NS) Co.Ac and Co.Ar (NS) L.Ac > Co.Ac (S) L.Ar > Co.Ar (S) Co(Ac+Ar) < L.Ac (NS) Co(Ac+Ar) < L.Ar (S)	L.Ac and L.Ar (NS) Co.Ac and Co.Ar (NS) L.Ac > Co.Ac (S) L.Ar > Co.Ar (S) Co(Ac+Ar) < L.Ac (NS) Co(Ac+Ar) < L.Ar (S)

Among species recorded for the genus *Aporrectodea* in Elburz region, *Ap. trapezoides* has been frequent and collected from humid habitats like farming areas (Latif *et al*., 2009). In northern parts of Sistan and Balouchestan Province, *Ap. trapezoides* was found infrequently but *Ap. caliginosa* and *Ap. rosea* were frequent and found together or lonely. These species resemble each other in ecological

preferences (Omodeo & Martinucci, 1987; Mirmonsef *et al*., 2011). Observations that *Ap. caliginosa* and *Ap. rosea* occur together at lower abundances and densities while they occur significantly at higher amounts where they are alone, suggests that these species compete with each other.
Another species of this genus, *Ap. longa* belongs to the endo-anecic ecological group and have widespread distribution in the Palearctic region.

Eis. tetraedra prefers highly moist soils and especially found in the banks of streams (Latif *et al*., 2009). Specimens of this species were collected in the similar habitat in the studied region as well. The other identified species that prefer this habitat is *B. parvus*; this species prefers highly moist soils with high organic materials. In present study, it was found in the habitat similar to *Eis. tetraedra* but in different station. Specimens of *E. omranii* as a native species were collected under stones and in wood litter. This species was described by Latif, Malek and Csuzdi (2017) from Kermanshah Province based on five specimens. Collected specimens in this study in contrast to described specimens have less number of segments (Table 4).

Four of nine species (epigeic) occurred separately in one station where the species of genus *Aporrectodea* (endogeic) did not exist (Table 2); it can be suggested by differences in ecological preferences of earthworms. Species of genus *Aporrectodea* prefer basic soils but epigeic species occur in organic matter-rich soils (Paoletti, 1999); also, endogeic species live deep in the soil while epigeics in the soil covering litter layer or the uppermost horizon (Edwards, 2004).

Specimens of *Ap. caliginosa*, *Ap. rosea*, *Ap. trapezoides*, *E. andrei/fetida*, *E. omranii*, and *Eis. tetraedra* from northern parts of Sistan and Balouchestan Province are longer than Elburz and/or Zagros specimens. The total number of segments of *Ap. trapezoides* and *Ap. longa* from northern parts of Sistan and Balouchestan Province is more than Elburz and/or Zagros regions but it is vice versa for *E. omranii* (Table 4).

The accumulating data about earthworm diversity in different parts of Iran will be led to an important paper discussing relationships between Iranian earthworm fauna and the fauna of adjacent countries. According to recorded data from different parts of Iran, there is some faunistic similarities between north of Iran and Turkey (Misirlioğlu *et al*., 2006). But no comparisons are possible between the eastern parts and eastern neighbors of Iran because no records of earthworms are available in these regions.

TABLE 4. Comparison of length (mm) and total segments of earthworms between northern parts of Sistan and Balouchestan Province (npSBP) and previous studied regions.

Species	Character	Elburz	Reference	Zagros	Reference	npSBP
		Min-Max		Min-Max		Min-Max
Ap. caliginosa	Length	60-130	Latif *et al*. (2009)	80-120	Latif *et al*. (2017)	130-140
	Segments	100-160		80-100		110-117
Ap. trapezoides	Length	60-130	Mirmonsef *et al*. (2011)	60-140	Latif *et al*. (2017)	141-150
	Segments	100-160		100-180		184-190
Ap. rosea	Length	20-110	Latif *et al*. (2009)	60-120	Latif *et al*. (2017)	130-152
	Segments	100-150		60-130		115-132
Ap. jassyensis	Length	60-190	Latif *et al*. (2009)	60-190	Latif *et al*. (2017)	120-132
	Segments	100-120		100-120		100-120
Ap. longa	Length	-	-	60-190	Latif *et al*. (2017)	159-166
	Segments	-		200-210		210-220

B. parvus	Length	-	-	60-65	Latif *et al.* (2017)	58-66
	Segments			60-95		63-70
E. andrei/fetida	Length	26-130	Latif *et al.* (2009)	30-130	Latif *et al.* (2017)	130-135
	Segments	60-110		70-110		105-110
E. omranii	Length	-	-	55-72	Latif *et al.* (2017)	111-120
	Segments	-		115-118		92-96
Eis. tetraedra	Length	20-80	Latif *et al.* (2009)	30-80	Latif *et al.* (2017)	90-103
	Segments	65-100		70-100		80-85

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