Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 13(3), 1573-1584, 2023
Journal of the Institute of Science and Technology, 13(3), 1573-1584, 2023
ISSN: 2146-0574, eISSN: 2536-4618
Biology **DOI: 10.21597/jist.1330703**
Research Article
Received: 21.07.2023 **Accepted: 07.08.2023**

To Cite: Aykut, M. & Tuğal, İ. (2023). The influence of Altitude on the Species Composition of Diving Beetles (Coleoptera; Adephaga; Dytiscidae) of Eastern and South Eastern Region of Turkey. *Journal of the Institute of Science and Technology*, 13(3), 1573-1584.

The influence of Altitude on the Species Composition of Diving Beetles (Coleoptera; Adephaga; Dytiscidae) of Eastern and South Eastern Region of Turkey

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Highlights:
- Altitudinal gradients
- Distribution of species
- Entropy measurements

Keywords:
- Adephaga
- Dytiscidae
- Species richness
- Elevation
- Türkiye

ABSTRACT:

This study was carried out between 2013 and 2019 in five provinces located in Eastern and South Eastern Anatolian Region of Turkey. The dytiscid specimens were collected from a total of 226 sampling sites that altitudes varied between 500 and 2,700 meters. The 226 sampling sites were classified into one of six altitudinal levels defined by semi open intervals with amplitude of 300 m. A total of 45 species belonging to the family Dytiscidae were identified. A detailed ecological analysis related to altitude is made by means of the distribution of 45 identified species. The richness of species was analyzed at different altitudinal levels. The indicator species were determined by establishing their altitude profile in terms of reciprocal species-factor information. The species density is highest in altitudinal level 2 (800-1100m) and is gradually decrease by increasing of altitudinal level. Ten representative species are placed into three groups: species occurring at high altitude; species present at low altitude and species occurring along the entire altitudinal gradient.

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A part of this study was presented orally in summary in 7th National Environment Congress, held online on December 17, 2022, Ankara, Türkiye

INTRODUCTION

The members of beetle family Dytiscidae are known as diving beetles and can be found in nearly all types of aquatic habitats from sea level (Hájek & Reiter, 2014; Balke et al., 2020) to high elevation (Brancucci & Hendrich, 2008). Besides being well swimmers the major members of the family are also good flyers. Thanks to this ability in some case they can move from permanent habitats to ephemerals one. Thus in field studies they could be found in unpredictable sites (Miller & Bergsten, 2016). Diving beetles are represented by 182 genera and approximately 4,600 species around the world (Nilsson & Hájek, 2023a). These values are; 80 genera and around 650 species in Palearctic region (Nilsson & Hájek, 2023b). In Turkey so far numerous faunal field studies have been conducted on the family Dytiscidae. As a result of mentioned studies a total of 165 species belong to 28 genera have been recorded, from of these 38 are endemic for Turkey (Erman & Erman, 2002; 2004; Erman & Fery, 2006; Darılmaz & Kıyak, 2009; 2010; Fery, 2009; Fery & Erman, 2009; Fery & Hendrich, 2011a,b; Fery & Przewozny, 2011; Hájek et al., 2011, Hernando et al., 2012; Vorst & Fery, 2014; Aykut & Fery, 2017; Aykut, 2018; 2022; Aykut &Taşar, 2018; Darılmaz et al., 2018; Erman et al., 2018; Aykut et al., 2018; 2019; 2021; Aykut & Tusun, 2022; Nilsson & Hájek, 2023b).

The altitude is greatly influence the distribution and specific composition of dytiscid beetles by affecting the characteristics of aquatic sites (Touaylia et al., 2011; Benzina et al., 2020). To the best of our knowledge; despite the numerous faunistic studies of dytiscid beetles of Turkey, no study was made that illustrate the effect of altitude on species distribution. With this study we aimed to study the relationship of the distribution and the altitude of the diving beetles sampled from Eastern and Southeastern Anatolian Region of Turkey.

MATERIALS AND METHODS

Dytiscid specimens were collected from various aquatic sources of Adıyaman, Batman, Bingöl, Diyarbakır and Mardin provinces which located in Eastern and Southeastern Anatolian Region of Turkey (Figure 1.) using nets with meshes diameters of 0.5-1 mm during the 2013-2019 periods. The handheld GPS tool (Magellan Explorist 610) was used for the information's of the localities. Collected specimens were fixed in alcohol solution and bring to laboratory. In laboratory a small paintbrush and ultrasonic cleaner (Augusta GS3) was used to remove the clay and muddy substances on the surfaces of collected specimens. The specimens which collected from the study area have been deposited in the private collection of the correspond author at Dicle University, Ziya Gökalp Education Faculty, Diyarbakır, Turkey.

The specimens were collected from a total of 226 sampling sites that altitudes varied between 510 and 2700 meters; 35 from Adıyaman, 39 from Batman, 60 from Bingöl, 58 from Diyarbakır and 34 from Mardin provinces. The 226 sampling sites were classified into six equidistant altitudinal levels with amplitude of 300 m. Level 1; 500–800 m and contains 52 sampling sites; level 2; 800–1100 m and contains 94 sampling sites; level 3; 1100–1400 m and contains 31 sampling sites; level 4; 1400-1700 m and contains 24 sampling sites; level 5; 1700-2000 m and contains 17 sampling sites and level 8 heights above 2000 m. The map of the study area which includes the sampling sites is given in Figure 1.

The sampling quality was evaluated by comparing the values obtained with the entropy measurements, taking into account the altitude factor. The entropy measurement method used in the study was proposed by Daget et al. (1972). Gonzalez et al. (1994) and Touaylia et al. (2011) applied this method to their studies.

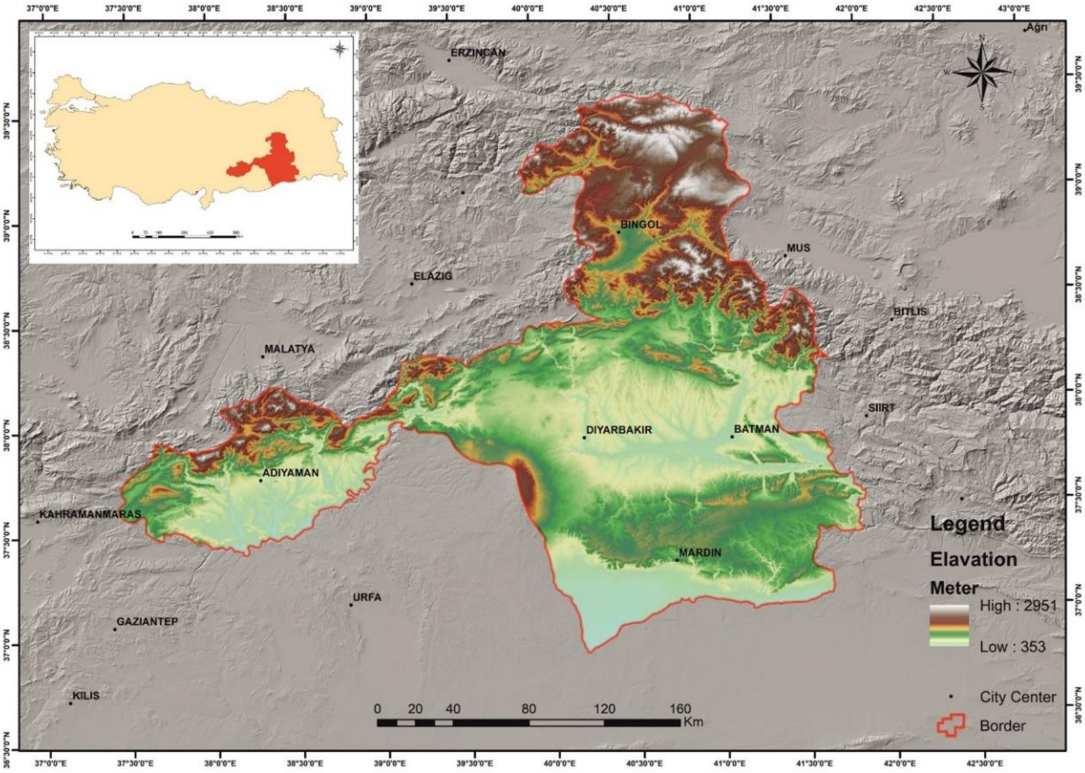

Figure 1. Map of the study area

Entropy is a measure of the disorder or uncertainty in a system, or vice versa, the amount of information. It gives us information about the system. It acts as a guide for learning something about the system. First, the concept of entropy was introduced in thermodynamics by Rudolf Clausius. The second law of thermodynamics is explained by entropy. The entropy of isolated systems does not decrease. Ludwig Boltzmann used entropy to measure disorder in statistical mechanics (Boltzmann, 1964; Solé & Valverde, 2004). Shannon used for communication systems (Shannon, 1948). It used in many scientific fields, such as statistical physics, chemistry, biology, information theory, computer science, communication. (Ben-Naim, 2008; Ribeiro et al., 2021). Shannon entropy is widely used to measure uncertainty and amount of information in probabilistic structures (Tuğal & Karcı, 2019, 2020). It defined as:

$$H(X) = -\sum_{i=1}^{n} p_i * log_2(p_i) \quad (1)$$

n is the number of states. p is the probability of each state. $X = \{p_i,\ i = 1, \dots, n\}$

For altitudinal level Daget *et al.* (1972) proposed entropy measure same as Shannon where *NR* = total number of sampling sites (226); *NK* = number of altitudinal levels considered (= 6) and *R(K)* = number of sampling sites at each altitudinal level. In fact, a statistical/probabilistic data is provided by looking at which species are found at altitudinal levels. By measuring the amount of information with entropy on this data, it is tried to understand the direction of the distribution of species at altitudinal levels and what variety of species they contain.

$$H(L) = \sum_{1}^{NK} \frac{R(K)}{NR} * log2\left(\frac{NR}{R(K)}\right) \quad (2)$$

Absolute frequencies were determined for each species at each altitudinal level according to the presence and absence of species. Corrected frequency [*C(K)*] is used to avoid uniformity in distribution for each species. We used the formula established by Daget and Gordon (1982). Here; *U(K)* = number of sampling sites at each altitudinal level in which the species is present and *U(E)* = total number of sampling sites in which the species is present.

$$C(K) = \frac{U(K)}{R(K)} : \frac{U(E)}{NR} \tag{3}$$

At an altitudinal level, the quantity of information provided by a species holds according to whether it exists or not can be measured by the following formula proposed by Gordon (1968). Here; *E* = represents species and *L* = represents altitudinal level as a factor. *V(K)* = total number of sampling sites at each altitudinal level where the species *E* is absent. *V(E)* = total number of sampling sites where the species E is absent. *I (L;E)* = presents a total amount of information based on whether a species is at all altitudinal levels. It is an indicative measure obtained by considering all altitudinal levels related to the species.

$$I(L;E) = \sum\nolimits_{1}^{NK} \frac{U(K)}{NR} * log2(\frac{U(K)}{R(K)}) * \frac{NR}{U(E)} + \sum\nolimits_{1}^{NK} \frac{V(K)}{NR} * log2(\frac{V(K)}{R(K)}) * \frac{NR}{V(E)} \tag{4}$$

The calculation of the abscissa “G” of the barycenter was assessed according to Daget and Gordon (1982). The ecological profile information’s of each species were obtained. Here; *C(K)* = index of corrected frequency for each species at each altitudinal level and *d (K)* = number of the corresponding altitude class.

$$G = \frac{\sum_{1}^{NK} \mathrm{C(K)}*\mathrm{d(K)}}{\sum_{1}^{NK} \mathrm{C(K)}} \tag{5}$$

We used two new formalizations for species entropy value. By dividing the frequency of each species at each altitudinal level by the total frequency of that species at all altitudinal levels, the *p* value that we mentioned in Shannon entropy was obtained. *NS(K)* = the frequency of each species at each altitudinal level. $HA(S)_i$ is the entropy of the each species. This entropy can be used to evaluate and compare each species at the altitudinal level. A single species has an effect on the entropy measure with its distribution over all altitudinal levels.

$$HA(S)_i = \sum_{1}^{NK} \frac{NS(K)}{\sum_{1}^{NK} NS(K)} * log2(\frac{NS(K)}{\sum_{1}^{NK} NS(K)}) \tag{6}$$

In another entropy calculation, the divisor at *p* is the total frequency of all species at each altitudinal level. *SN* is the total number of species detected in the area as seen in Table 1. At each altitudinal level, a measurement is obtained considering the effect of all species. All species influence the entropy measure. It offers a measure that concerns the whole.

$$HS(S)_i = \sum_{1}^{NK} \frac{NS(K)}{\sum_{1}^{SN} NS(K)} * log2(\frac{NS(K)}{\sum_{1}^{SN} NS(K)}) \tag{7}$$

The aim of the proposed entropy calculations is to detect influential species in this area. When the results obtained are compared with Figure 3, the accuracy of the results will be seen.

The python's data visualization package matplotlib (Matplotlib 3.1.1) was used to demonstrate the altitudinal quartile range of the each collected species. Here the altitudinal values were processed separately for each species. Thus, the altitudinal median, mean and outlier values of each species could be visualized.

RESULTS AND DISCUSSION

A total of 45 species belong to 18 genera of family Dytiscidae were identified from the study area (Table 1.). The score of *I (L; E)* was 1.620, while maximum entropy was 2.585. The ratio between those two scores was 0.626. This ratio shows that the altitudinal factor has been sufficiently sampled; however, because of the low average altitude of studied provinces (Adıyaman = 670m, Batman = 570m, Bingöl = 1160m, Diyarbakır = 670m and Mardin = 1080m) (Figure 1) the first two altitudinal levels frequency was high (64.6%), thus some information's may lost.

The species richness at different altitudinal levels shown in Figure 2. According to the scores obtained from the study, the greatest specific abundance was observed at level 2 (800-1100m). The species density was gradually decrease by increasing of altitudinal levels.

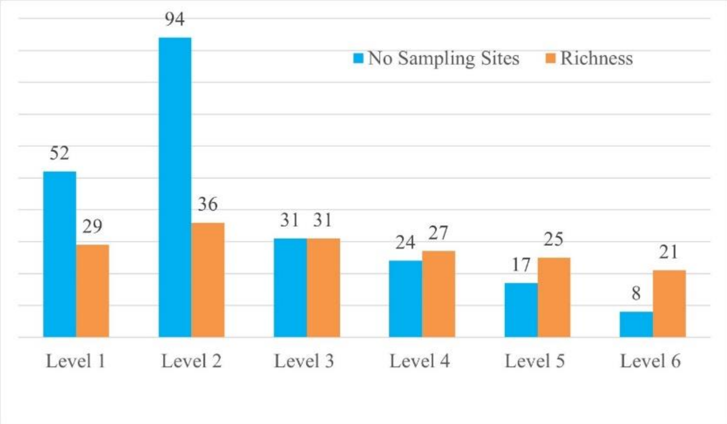

Figure 2. Relationship between number of sampling sites and species richness at six altitudinal levels. L1 = 500-800m; L2 = 800-1100m; L3 = 1100-1400m; L4 = 1400-1700m; L5 = 1700-2000m; L6 = >2000m

The ecological profile of absolute and corrected frequencies for each species at each altitudinal level is given in Table 1. This table also demonstrates the indicator values [*I (L; E)*] of collected species in every altitude levels. The species with high I (L; E) scores could be considered as altitude indicator species. In the current study; ten species with high I (L; E) scores (indicated with an asterisk) are selected as ''altitude indicator species''.

Table 1. Values of absolute and corrected frequencies. mutual information I (L; E) and "G" value of the barycenter for each aquatic beetle species in southern provinces of Turkey. L1 = 501-800m; L2 = 801–1100 m; L3 = 1101–1400 m; L4 = 1401–1700 m; L5 = 1701–2000 m; L6 = >2000 m

	Absolute frequencies								Corrected frequencies						
Species	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**T**	**I (L;E)**	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**"G"**
Agabus biguttatus (Olivier, 1795)	12	17	4	9	5	3	50	0.0021	1.04	0.82	0.58	1.70	1.33	1.70	3.91
Agabus bipustulatus (Linnaeus, 1767)	20	25	14	9	9	0	77	0.0083	1.13	0.78	1.33	1.10	1.55	-	3.20
Agabus caraboides Sharp, 1882	3	9	4	0	2	2	20	0.0007	0.65	1.08	1.46	-	1.33	2.83	4.19
Agabus conspersus (Marsham, 1802)	11	18	2	8	3	0	42	0.0003	1.14	1.03	0.35	1.79	0.95	-	3.07
Agabus didymus (Olivier, 1795)	0	9	0	0	0	0	9	0.0002	-	2.40	-	-	-	-	2.00
Agabus dilatatus (Brullé, 1832)*	0	0	0	4	4	0	8	0.0462	-	-	-	4.71	6.65	-	4.59
Agabus nebulosus (Forster, 1771)*	14	19	8	5	3	1	50	0.0512	1.22	0.91	1.17	0.94	0.80	0.57	3.16
Bidessus calabricus Guignot, 1957	8	16	6	3	0	2	35	0.0002	0.99	1.10	1.25	0.81	-	1.61	3.44
Bidessus unistriatus (Goeze,1777)*	2	14	3	0	3	0	22	0.0547	0.40	1.53	0.99	-	1.81	-	3.28
Colymbetes fuscus (Linnaeus, 1758)	7	16	0	1	0	2	26	0.0017	1.17	1.48	-	0.36	-	2.17	3.59
Deronectes evelynae Fery & Hosseinie, 1998	0	0	1	0	0	0	1	0.0002	-	-	7.29	-	-	-	3.00
Deronectes kabılcevz Aykut, Yıldırım, Tusun & Fery,2019	0	0	1	0	0	0	1	0.0002	-	-	7.29	-	-	-	3.00
Deronectes propedoriae Aykut, Yıldırım, Tusun & Fery, 2019	0	0	1	0	0	0	1	0.0002	-	-	7.29	-	-	-	3.00
Dytiscus marginalis marginalis Linnaeus, 1758	2	8	0	0	0	2	12	0.0002	0.72	1.60	-	-	-	4.71	4.57
Eretes sticticus (Linnaeus,1767)	0	0	1	0	0	0	1	0.0002	-	-	7.29	-	-	-	3.00

Table 1. Continued

Species	L1	L2	L3	L4	L5	L6	T	I (L;E)	L1	L2	L3	L4	L5	L6	"G"
Graptodytes flavipes (Olivier,1795)	1	10	0	4	0	0	15	0.0003	0.29	1.60	-	2.51	-	-	3.07
Graptodytes veterator behningi Zaitzev, 1927	0	2	3	1	2	0	8	0.0391	-	0.60	2.73	1.18	3.32	-	3.92
Hydroglyphus geminus (Fabricius, 1792)	22	31	7	5	5	1	71	0.0013	1.35	1.05	0.72	0.66	0.94	0.40	3.00
Hydroglyphus pusillus (Fabricius, 1781)*	5	5	0	0	0	0	10	0.0521	2.17	1.20	-	-	-	-	1.36
Hydroporus discretus Fairmaire and Brisout, 1859	10	20	0	2	0	2	34	0.0011	1.28	1.41	-	0.55	-	1.66	3.32
Hydroporus inscitus Sharp, 1882	0	0	1	0	0	0	1	0.0002	-	-	7.29	-	-	-	3.00
Hydroporus kozlovskii Zaitzev, 1927	0	4	0	0	0	0	4	0.0008	0	-	2.40	-	-	-	2.00
Hydroporus marginatus (Duftschmid, 1805)	2	15	0	0	0	0	17	0.0036	0.51	0.51	2.12	-	-	-	1.81
Hydroporus planus (Fabricius, 1782)	9	20	8	3	3	1	44	0.0008	0.89	0.89	1.09	1.33	0.64	0.91	3.27
Hydroporus pubescens (Gyllenhal, 1808)*	10	24	3	6	3	2	48	0.4607	0.91	0.91	1.20	0.46	1.18	0.83	3.58
Hydroporus tessellatus (Drapiez, 1819)	2	15	2	1	2	1	23	0.0011	0.38	0.38	1.57	0.63	0.41	1.16	3.76
Hydroporus transgrediens Gschwendtner, 1923	4	14	4	6	5	3	36	0.0012	0.48	0.48	0.93	0.81	1.57	1.85	4.30
Hydrovatus cuspidatus (Kunze, 1818)	0	1	5	7	0	0	13	0.0102	0	-	0.18	2.80	5.07	-	3.61
Hygrotus confluens (Fabricius, 1787)	0	0	4	5	4	0	13	0.0059	0	-	-	2.24	3.62	4.09	4.19
Hygrotus impressopunctatus (Schaller, 1783)	2	2	4	1	1	1	11	0.0032	0.79	0.79	0.44	2.65	0.86	1.21	4.05
Hygrotus inaequalis (Fabricius, 1777)*	19	22	8	0	0	0	49	0.0667	1.42	1.69	1.08	1.19	-	-	1.87
Hygrotus marklini (Gyllenhal, 1813)*	0	0	0	3	1	1	5	0.0654	0	-	-	-	5.65	2.66	5.00
Hygrotus saginatus (Schaum, 1857)	0	1	4	4	1	0	10	0.0054	0	-	0.24	2.92	3.77	1.33	3.75
Ilybius chalconatus (Panzer. 1796)	0	10	4	9	0	0	23	0.0099	0.16	-	1.05	1.27	3.68	-	3.44
Ilybius fuliginosus (Fabricius. 1792)	5	15	7	1	0	2	30	0.0021	0.72	0.72	1.20	1.70	0.31	-	3.57
Laccophilus hyalinus (De Geer, 1774)	11	24	7	4	5	2	53	0.0006	0.90	0.90	1.09	0.96	0.71	1.25	3.59
Laccophilus minutus (Linnaeus, 1758)	4	24	5	7	3	2	45	0.0011	0.39	0.39	1.28	0.81	1.46	0.89	3.81
Laccophilus poecilus Klug, 1834*	9	21	5	0	0	0	35	0.0477	1.12	1.12	1.44	1.04	-	-	1.98
Nebrioporus airumlus (Kolenati, 1845)*	1	1	0	0	2	2	6	0.0512	0.72	0.72	0.40	-	-	4.43	5.36
Nebrioporus stearinus (Kolenati, 1845)	0	24	4	5	7	0	40	0.0001	0.31	-	1.44	0.73	1.18	2.33	3.77
Oreodytes davisii davisii (Curtis, 1831)	0	0	0	0	2	1	3	0.0006	0	-	-	-	-	8.86	5.52
Platambus lunulatus (Fischer von Waldheim, 1829)	3	6	3	2	1	1	16	0.0280	0.81	0.81	0.90	1.37	1.18	0.83	3.82
Platambus maculatus (Linnaeus, 1758)	1	1	0	0	2	0	4	0.0008	1.09	1.09	0.60	-	-	6.65	4.26
Rhantus suturalis (W.S. MacLeay, 1825)	2	6	0	0	0	0	8	0.0018	1.09	1.09	1.80	-	-	-	1.62
Scarodytes halensis (Fabricius, 1787)*	15	29	9	7	5	1	66	0.0824	0.99	0.99	1.06	0.99	1.00	1.01	3.23

Total number of sampling sites: 226. L1: 52; L2: 94; L3:31; L4:24; L5:17; L6:8 sampling sites.

The altitudinal quartile range of identified species is demonstrated on Figure 3. "G" values that are given in Table 1 show the ecological profiles of the species. With the comparing the "G" values and the ''altitudinal quartile range'' of the species (Figure 2); it has been observed that the ''G'' values given in Table 1 are directly proportional to the altitudinal quartile range shown in Figure 3.

For each collected species two separate entropy values are obtained. These; the entropy value obtained from the total frequency of each species at all altitudinal levels [HA*(S)*] and the entropy value obtained from the total frequency of all species at each altitudinal level [HS*(S)*] (Figure 4). The sum of species entropy at the L2 and L3 altitudinal levels are higher at HS(S). For HA(S), the sum of species entropy is higher at L1 and L2 altitudinal levels. This show that the species are not homogeneously distributed at altitudinal levels and each species can be found more intensely at different altitudinal levels.

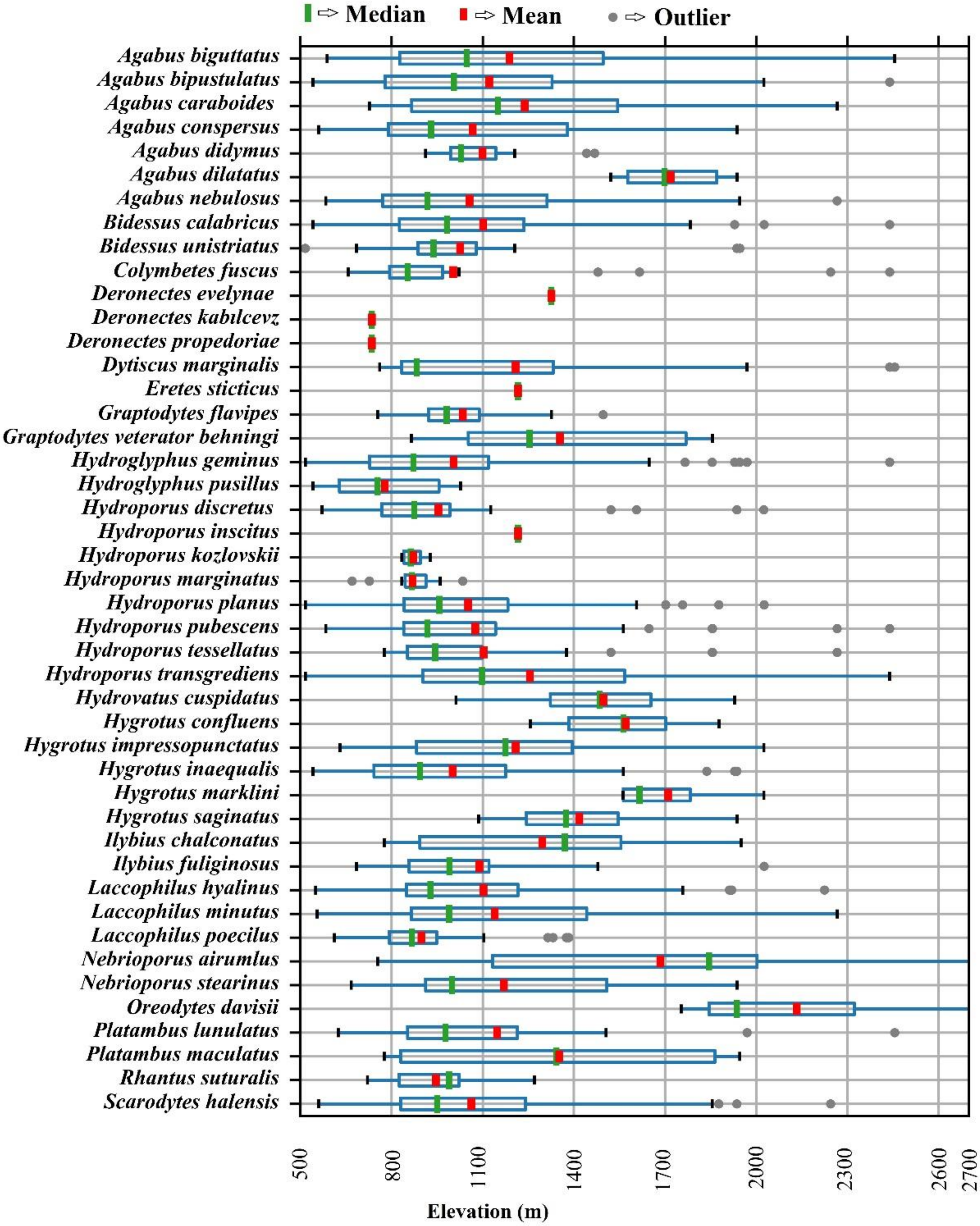

Figure 3. The altitudinal quartile range of the each collected species

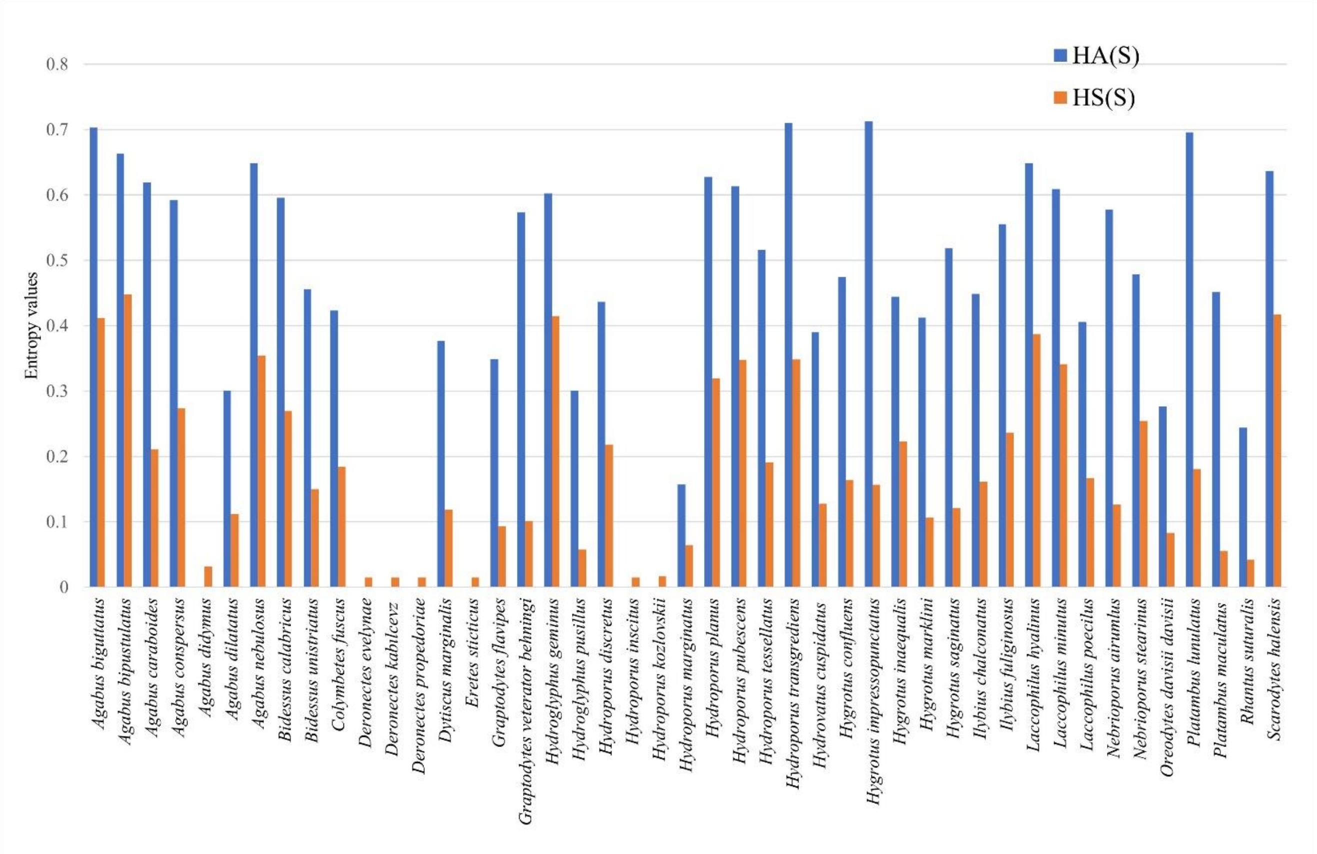

Figure 4. Entropy values of each collected species. (HA*(S)* = sum of entropy obtained by using the ratio of the number of a species at each altitudinal level to the total number of that species at all altitudinal levels and HS*(S)* = sum of entropy obtained by the ratio of the number of a species at each altitudinal level to the total number of all species at that each altitudinal level

By taking the altitudinal preferences the 10 selected representative species can be categorized in to 3 groups; a) species present in lowland areas, b) species occur in highland areas and c) species occur along the entire altitudinal gradient.

a) Species present in lowland areas

***Hydroglyphus geminus* (Fabricius, 1792):** The specimens are found in many habitats. It was collected from a total of ten sites with altitudes between 540 and 1.020 m. Specimens were found in small and stagnant water sources with the bottom of fine sandy.

***Hygrotus inaequalis* (Fabricius, 1777):** The specimens of this species can be found in nearly every water type though the species is rare in temporary puddles (Cuppen, 1983). In current study the specimens were collected from a total of 49 sites with altitudes ranging from 540 to 1.380 m, with almost all types of water sources.

***Laccophilus poecilus* Klug, 1834:** The specimens report from stagnant water sources. It also reported that the specimens are mainly known from brackish water, where it occurs in sheltered bays on silty bottoms with dense vegetation (Biström *et al.*, 2015). In our study area the specimens were collected from a total of 35 sites with altitudes ranging from 610 to 1.380 m, with almost all types of water sources.

b) Species present in highland areas

***Agabus dilatatus* (Brullé, 1832):** The specimens are, like most other species in the *Agabus guttatus* group, restricted to springs, seepages and small streams. It also occurs and in mountain streams in forested areas and low elevations in the mountains (Scheers & Thant, 2017). In our study area the specimens were collected from a total of 8 sites with altitudes ranging from 1.520 to 1.930 m. We came across to the specimens of this species only in the mountainous regions of Bingöl province. This species was not found in other provinces of our study area.

***Hygrotus marklini* (Gyllenhal, 1813):** This species inhabits open seasonal ponds usually that are sparsely vegetated and largely confined to ground abandoned gravel and clay pits or stone quarries (Nilsson & Holmen, 1995). In our study area the specimens were collected from a total of 5 sites with altitudes ranging from 1560 to 2020 m.

***Nebrioporus airumlus* (Kolenati, 1845):** This is one of the most widespread and common species of Nebrioporus. This species is mostly found in rivers and streams, also in the highland's lakes and puddles. In Turkey it was found in high elevations (Toledo, 2009). In our study area the specimens were collected from a total of 6 sites with altitudes ranging from 754 to 2.710 m, 4 of which have values over 1.750 m.

c) Species present along the entire altitudinal gradient.

***Agabus nebulosus* (Forster, 1771):** This species could be found in lentic (pond and irrigation canal) and lotic (river and high mountain streams) habitats (Touaylia et al., 2011). Its presence has been detected at different elevations in most of the previous studies in Turkey (Darılmaz &Kıyak, 2009). In our study area the specimens were collected from a total of 50 sites with altitudes ranging from 580 to 2.220 m.

***Bidessus unistriatus* (Schrank, 1781):** The specimens were collected from stagnant small puddles with vegetation, shallow shores of ponds and river banks from a total of 22 sites with altitudes ranging from 510 to 1,940 m.

***Hydroporus pubescens* (Gyllenhal, 1808):** Plains and low mountains in stagnant fresh or brackish waters is mainly habitat for members of the species (Touaylia et al., 2011). The elevation of 48 collecting sites range from 580 to 2.440 m. It can also be seen in small puddles, especially in meadow grass.

***Scarodytes halensis* (Fabricius, 1787):** This species is the third most widespread species in our study area. The specimens were collected from a total of 66 sites with altitudes ranging from 560 to 2.240 m. It has been isolated from slow-flowing water sources and stream puddles with sand and slimy bottom.

Overall; *Agabus bipustulatus*, *Hydroglyphus geminus*, S*carodytes halensis*, *Laccophilus hyalinus*, *Agabus biguttatus*, *Agabus nebulosus*, *Hygrotus inaequalis*, *Hydroporus pubescens*, *Laccophilus minutus* and *Hydroporus planus* were the most widespread species found in our study area. These ten species were found, respectively: *Agabus bipustulatus* in77 sites, *Hydroglyphus geminus* in 71 sites, S*carodytes halensis* in 66 sites, *Laccophilus hyalinus* in 53 sites, *Agabus biguttatus* and *Agabus nebulosus* in 50 sites, *Hygrotus inaequalis* in 49 sites, *Hydroporus pubescens* in 48 sites, *Laccophilus minutus* in 45 sites and *Hydroporus planus* in 44 sites. In contrast to these species; *Deronectes evelynae*, *Deronectes kabilcevz*, *Deronectes propedoriae*, *Eretes sticticus* and *Hydroporus inscitus* were restricted to a single site each.

CONCLUSION

In conclusion; a total of 45 dytiscid species were collected from a total of 226 sites ranging with altitudes of 510 and 2.710 meters. The species density was lowest in level 1(500-800m) and the highest species density in level 2. After level 2, the species density was gradually decrease by increasing of elevation. 10 species were determined as indicator species with regard of altitude. Taking into account their altitudinal preferences the 10 out of 45 identified species with high I(L;E) score were selected as indicator species. Altitude could be considered among the physical factors that affect the aquatic beetle's distribution.

The effect of altitude is also combined with other environmental variables such as temperature, pH value, conductivity, turbidity, substratum, water flow, and stream geomorphology along altitudinal gradients.

ACKNOWLEDGEMENTS

A part of this study was presented orally in summary in 7th National Environment Congress, held online on December 17, 2022, Ankara, Turkey.

Conflict of Interest

The authors declare no potential conflict of interest.

Author's Contributions

The authors declare that they have contributed equally to the article.

REFERENCES

Aykut, M. & Fery, H. (2017) *Scarodytes costatus* nov. sp. from the Bingöl Province in Turkey, the first species of the genus with costate elytra (Insecta: Coleoptera: Dytiscidae: Deronectina). Linzer Biologische Beiträge, 49, 395–414.

Aykut, M. (2018) The Diving Beetle Fauna of Diyarbakır and Bingöl Provinces, Turkey (Coleoptera: Dytiscidae) with a New Record. Pakistan Journal of Zoology, 50 (1), 65–74.

Aykut, M., Taşar, G.E. & Fery, H. (2018) *Deronectes taron* sp. n. from the eastern Anatolian region of Turkey (Coleoptera, Dytiscidae, Hydroporinae). Zootaxa, 4422 (2), 403–410.

Aykut, M. & Taşar, G.E. (2018) Contributions to the knowledge of Adephagan fauna in Adıyaman Province, Turkey (Coleoptera: Dytiscidae, Gyrinidae, Haliplidae and Noteridae). Munis Entomology & Zoology, 13, 249–255.

Aykut, M., Yıldırım, İ.H., Tusun, S. & Fery, H. (2019) *Deronectes kabilcevz* sp. n. and *D. propedoriae* sp. n. from south-eastern Anatolia (Turkey) (Coleoptera, Dytiscidae, Hydroporinae). *Zootaxa*, 4691 (1), 5–10.

Aykut, M., Taşar, G. E. & Fery, H. (2021) *Bidessus anatolicus adiyaman* ssp. n. from Adyaman province, southern Turkey (Coleoptera, Dytiscidae, Bidessini). Zootaxa, 5027(4), 563–575.

Aykut, M. (2022). Mardin ili Dytiscidae (Insecta: Coleoptera) Faunasına Katkılar. Journal of the Institute of Science and Technology, 12(4), 2027-2033.

Aykut, M., & Tusun, S. (2022). Contributions to the knowledge of Dytiscidae (Insecta: Coleoptera) Fauna of Batman Province. Türk Doğa ve Fen Dergisi, 11(4), 155-159.

Balke, M., Megna, Y.S., Zenteno, N., Figueroa, L. & Hendrich, L. (2020) New *Liodessus* species from the high Andes of Peru (Coleoptera: Dytiscidae, Bidessini). Zootaxa, 4852(2), 151–165.

Ben-Naim, A. (2008) A Farewell To Entropy: Statistical Thermodynamics Based On Information. World Scientific Publishing Co. Pte. Ltd.

Benzina, I., Si Bachir, A., Ghazi, C., Santoul, F., & Céréghino, R. (2020) How altitudinal gradient affects the diversity and composition of benthic insects in arid areas streams of northern East Algeria?. Biologia, *75*(4), 567–577.

Boltzmann, L. (1964) Lectures on Gas Theory. University of California Press.

Brancucci, M. & Hendrich, L. (2008) 5100 m above sea level: *Agabus joachimschmidti* sp. n. and notes on other high altitude diving beetles from Tibet and Bhutan (Coleoptera, Dytiscidae). Zootaxa, 1825(1), 51–58.

Biström, O., Nilsson, A.N. & Bergsten, J. (2015) Taxonomic revision of Afrotropical *Laccophilus* Leach, 1815 (Coleoptera, Dytiscidae). ZooKeys, (542), 1–379.

Cuppen, J.G.M. (1983) On the habitats of three species of the genus *Hygrotus* Stephens (Coleoptera: Dytiscidae). Freshwater Biology, 13(6), 579–588.

Daget, P., Gordon, M. & Guillerm, J.L. (1972) Profils écologiques et information mutuelle entre espèces et facteurs écologiques [pp. 121–149]. In:Grundfragen um Methoden in der Pflanzensoziologie. Junk Publishers, La Hague, Netherlands.

Daget, P. & Gordon, M (1982) Analyse de l'écologie des espèces dans les communautés. Coll. d'écologie. Masson, Paris, pp. 1–163.

Darılmaz, M.C. & Kıyak, S. (2009) Checklist of Gyrinidae, Haliplidae, Noteridae and Dytiscidae of Turkey (Coloptera: Adephaga). Journal of Natural History, 43(25), 1585–1636.

Darılmaz, M.C. & Kıyak, S. (2010) New and Rare Water Beetles (Coleoptera: Haliplidae: Dytiscidae) for the Fauna of Turkey. Acta Zoologica Bulgarica, 62(1), 99–102.

Erman Ö.K, Erman O. (2002) First records of *Oreodytes* Seidlitz, 1887 (Dytiscidae, Coleoptera) from Turkey: *Oreodytes septentrionalis* (Gyllenhel, 1826) and *Oreodytes davisii* (Curtis, 1831). Turkish Journal of Zoology, 26(3): 295-299.

Erman, Ö.K. & Erman, O. (2004) First record of *Graptodytes bilineatus* (Sturm, 1835) (Coleoptera, Dytiscidae) from Turkey. Turkish Journal of Zoology, 28(1), 87–90.

Erman, Ö.K. & Fery, H. (2006) *Hydroporus neclae* sp. n. from north-eastern Turkey, a new member of the memnonius-group of *Hydroporus* Clairville (Coleoptera: Dytiscidae). Zootaxa, 1355, 39–47.

Erman, Ö.K., Taşar, G.E., Aykut, M. & Kurt, K. (2018) First record of *Hydaticus histrio* Clark, 1864 (Coleoptera, Dytiscidae) from Turkey. Acta Biologica Turcica, 31(4), 174–177.

Fery, H. & Erman, Ö.K. (2009) Five new species of the *longulus*-group of *Hydroporus* Clairville, 1806 from north-eastern Turkey (Coleoptera: Dytiscidae). Zootaxa, 2033, 1–12.

Fery, H. (2009) New species of the *Hydroporus longulus*group from Iran, Armenia and Turkey with a synopsis of the group (Coleoptera: Dytiscidae). Acta Entomologica Musei Nationalis Pragae, 49(2), 529–558.

Fery, H. & Hendrich, L. (2011a) *Hydroporus esersi* sp. n., a new diving beetle from southern Turkey (Coleoptera, Dytiscidae, Hydroporinae). Zootaxa, 2909, 38–46.

Fery, H. & Hendrich, L. (2011b) *Ilybius enpalaiatheka* sp. nov. from Anatolia, Turkey, with a revised key to males of the *Ilybius erichsoni* and *chalconatus* groups. Spixiana, 34, 39–46.

Fery, H. & Przewoźny, M. (2011) *Ilybius thynias* sp. n. from European Turkey (Coleoptera: Dytiscidae). Zootaxa, 2740, 59–67.

Gonzalez, G., Fernández-Aláez, M. & Cueto, J.A. (1994) Geographical distribution of Adephaga and Polyphaga (Coleoptera) in the Cantabrian Mountains (Spain): Specific richness and analysis of the altitude factor. Archiv fur Hydrobiologie. Stuttgart, 131(3), 353–380.

Gordon, M. (1968) Quelques applications de la notion de fréquence en écologie végétale (recouvrement, information mutuelle entre espèces et facteurs écologiques, échantillonnage). Oecology of Plants 3, 185–212.

Hájek, J., Šťastný, J., Boukal, M. & Fery, H. (2011) Updating the eastern Mediterranean *Deronectes* (Coleoptera: Dytiscidae) with the description of two new species from Turkey. Acta Entomologica Musei Nationalis Pragae, 51, 463–476.

Hájek, J. & Reiter, A. (2014) Adephagous water beetles (Coleoptera: Gyrinidae, Haliplidae, Noteridae, Dytiscidae) of Yemen and Dhofar region (Oman) with description of a new *Hyphydrus* from Socotra Island. Acta Entomologica Musei Nationalis Pragae, 54, 63–99.

Hernando, C., Aguilera, P., Castro, A. & Ribera, I. (2012) A new interstitial species of the *Hydroporus ferrugineus* group from north-western Turkey, with a molecular phylogeny of the *H. memnonius* and related groups (Coleoptera: Dytiscidae: Hydroporinae). Zootaxa, 3173, 37–53.

Miller, K.B. & Bergsten, J. (2016) Diving beetles of the world: Systematics and biology of the Dytiscidae. JHU Press.

Nilsson, A.N. & Holmen, M. (1995) The Aquatic Adephaga (Coleoptera) of the Fennoscandia and Denmark. Ii. Dytiscidae: II-Dytiscidea. Brill.

Nilsson, A.N. & Hájek, J. (2023a) Catalogue of Palearctic Dytiscidae (Coleoptera). World
Wide Web Electronic Publication, http://www.waterbeetles.eu [Accessed 3 June, 2023].

Nilsson, A.N. & Hájek, J. (2023b) A world catalogue of the family Dytiscidae (Coleoptera, Adephaga). World Wide Web Electronic Publication, http://www.waterbeetles.eu [Accessed 3 June, 2023]

Ribeiro, M., Henriques, T., Castro, L., Souto, A., Antunes, L., Costa-Santos, C. & Teixeira, A. (2021) The Entropy Universe. Entropy, 23(2), 222.

Scheers, K. & Thant, S. (2017) *Agabus didymus* (Olivier, 1795) and *A. dilatatus* (Brullé, 1832), two species new to the fauna of Croatia with notes on the ecology and distribution of both species (Coleoptera: Dytiscidae). Bulletin de la Société royale belge d'Entomologie/Bulletin van de Koninklijke Belgische Vereniging voor Entomologie, 153(1), 54–58.

Shannon, C.E. (1948). A Mathematical Theory of Communication. *Bell System Technical*

Solé, R.V. & Valverde, S. (2004) Information Theory of Complex Networks: On Evolution and Architectural Constraints. Complex Networks, 189–207.

Toledo, M. (2009) Revision in part of the genus *Nebrioporus* Régimbart, 1906, with emphasis on the *N. laeviventris*-group (Coleoptera: Dytiscidae). Zootaxa, 2040(1), 1–111.

Touaylia, S., Garrido, J., Bejaoui, M. & Boumaiza, M. (2011) Altitudinal distribution of aquatic beetles (Coleoptera) in northern Tunisia: relationship between species richness and altitude. The Coleopterists Bulletin, 65(1), 53–62.

Tuğal, İ. & Karcı, A. (2019) Comparisons of Karcı and Shannon entropies and their effects on centrality of social networks. Physica A: Statistical Mechanics and Its Applications, 523, 352–363.

Tuğal, İ. & Karcı, A. (2020) Determination of Influential Countries by Cultural and Geographical Parameters. Anemon Muş Alparslan University Journal of Social Sciences, 8(1), 179–188.

Vorst, O. & Fery, H. (2014). *Hydroporus emergens* sp. n. from south-western Turkey (Coleoptera: Dytiscidae). Tijdschrift voorEntomologie, 157, 145–149.