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A Field Study on Bio-Ecology of *Deronectes toledoi* (Coleoptera: Dytiscidae) in the Eastern Anatolia Region of Turkey

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ABSTRACT

Deronectes toledoi Fery, Erman and Hosseinie, 2001 (Dytiscidae) is an endemic aquatic beetle only known from Turkey (Erzurum, Toprakkale). Relatively little has been learned about this beetle since it was discovered. We conducted a study to determine some bio-ecological characteristics of *D. toledoi* and determine the impact of physico-chemical parameters on aquatic Coleoptera species diversity. Mature specimens of aquatic Coleoptera were collected once a month from vegetated part of the brook running parallel to the Erzurum-İspir road around Erzurum, Aziziye district, Toprakkale Village during March November 2009 period and were assessed in relation to environmental variables. Redundancy Analysis (RDA) showed that water temperature, dissolved oxygen and calcium explained 82 % of the taxa variance of the creek. Not only these parameters but also air temperature and precipitation were also found out to be important factors for the ecology of *D. toledoi*. Higher evenness in the creek showed that *D. toledoi* was not a dominant species but its tolerance to environmental parameters was higher than other species in the creek. This study was conducted to take a step to understand the habitat preferences of *D. toledoi* but further multidisciplinary studies of the biological diversity in streams, which are important for natural conservation, are necessary to understand the ecology of rare and endemic species.

Key words: Coleoptera, Dytiscidae, *Deronectes toledoi,* biodiversity, water quality, Turkey.

INTRODUCTION

The *Deronectes* group of genera comprise small diving beetles (Dytiscidae) which belong to the subfamily Hydroporinae, tribe Hydroporini. They often have a characteristic, quite flattened appearance and typically inhabit stony or gravelly rivers or lakes (Angus and Tatton, 2011) or submerged tree roots in small streams with sparse vegetation (Fery and Brancucci, 1997).

Deronectes has a predominantly Mediterranean distribution, ranging from North Africa and the Iberian Peninsula over most parts of central and northern Europe and the Middle East, with some species reaching central Asia (Fery and Brancucci, 1997; Fery and Hosseinie, 1998; Hajek *et al*., 2011; García-Vázquez *et al*., 2016).

Deronectes species are generalist predators, feeding on a range of small aquatic invertebrates, and having similar general ecologies across their geographical ranges, although differing markedly in latitudinal range size (Calosi *et al*., 2010).

Although distribution and habitat choice of most *Deronectes* species have been described (Fery and Brancucci, 1997; Fery and Hosseinie, 1998), knowledge remains limited (Calosi *et al*., 2010; Hajek *et al*., 2011).

Several new Dytiscidae from *Deronectes* were discovered in last years as a result of the extensive studies on running water habitats in Turkey (Fery *et al*., 2001; Hájek *et al*., 2011). All these *Deronectes* species are most probably highly endemic mountainous species and were collected from almost exclusively small springs, streams, and rivers (Hajek *et al*., 2011).

58 species of *Deronectes* were known to occur in the Palearctic region. Seventeen of these have been recorded from Turkey so far. Twelve of them are endemic to Turkey (Fery and Brancucci, 1997; Fery and Hosseinie, 1998; Fery *et al*., 2001; Hájek *et al*., 2011; Nilsson and Hájek, 2018). *Deronectes toledoi* is one of these endemic aquatic beetles only known from Turkey (Erzurum, Toprakkale) (Fery *et al*., 2001). But relatively little has been learned about this beetle since that time. The main objectives of the present study are to determine some bio-ecological characteristics of *D. toledoi* and determine the impact of physico-chemical parameters on aquatic insects species diversity.

MATERIAL AND METHODS

Study area and sampling methods

The study area is located in 75 km north-west of Erzurum Province of Turkey (Fig.1). Annual average temperature of the area was 9.5 °C (from - 0.6 to 17.3 °C) during the study period (Table 1). Monthly average precipitation for the area was 42 mm (from 29 to 83 mm) during the study period (Table 1).

Mature specimens of aquatic Coleoptera were collected once a month from the vegetated part of the brook running parallel to the Erzurum-İspir road around Erzurum, Aziziye district, Toprakkale Village (40^{0}14′235″ N 40^{0}59′195″ E, 2152 m) during March November 2009 period This brook had a 2 - 3 m broad, a depth of 0.5 - 1.0 m and slow water current.

Fig. 1. Location of the study site.

Table 1. Monthly fluctuations of physico-chemical parameters in the breeding habitat.

	Spring			Summer			Autumn		
Parameter	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**
Water temperature (°C)	5	2.9	20.2	13.3	18	16.3	4.6	5.8	4.1
Dissolved oxygen (mg O_2 /l)	8.67	9.7	9.92	9.02	8.5	10.15	11.5	11.7	9.7
pH	8	8.1	8.43	8.2	8.1	8.18	8.2	8.05	8.05
Conductivity (μS/cm)	428	358	345	459	418	398	387	400	420
Sodium (mg Na^+/l)	8.99	4.04	4.15	4.34	5.46	5.01	11.04	7.30	6.35
Potassium (mg K^+/l)	15.29	14.7	19.55	8.19	10.34	9.70	27.79	19.18	15.52
Magnesium (mg Mg^+/l)	4.42	3.14	3.01	4.19	4.19	3.86	8.49	8.62	8.53
Calcium (mg Ca^+/l)	79.18	58.88	59.71	86.57	70.95	72.65	170.52	183.33	164.88
Ammonium (mg $NH4^+$/l)	0.6	0.91	0.99	<0.01	0.65	0.39	<0.001	0.09	0.09
Nitrite (mg NO_2-/l)	0.13	0.09	-	<0.002	0.38	0.56	<0.002	<0.002	0.14
Nitrate (mg NO_3-/l)	5.45	2.19	1.08	0.39	1.52	3.99	7.41	7.41	6.75
Sulphate (mg $SO_4^=$/l)	14.59	8.71	4.26	12.7	7.01	5.24	8.53	8.53	8.61
Phosphate (mg PO_4^{-3}/ l)			-	-	-	-	<0.0173	<0.0173	<0.0173
Flour (mg F^-/l)	0.11	0.08	0.07	0.2017	0.074	0.1	0.05	0.05	0.16
Chlorine (mg Cl^-/l)	4.99	2.28	1.43	4.63	4.06	4.40	3.93	3.93	4.7
Air Temperature (°C)	1	4.4	10	14.7	17.3	17	12.4	8.7	1.8
Monthly Average Precipitation (mm)	59.5	44.7	55.8	83	36.6	29	49.2	60.4	42

The insects were collected in the habitat by means of a sieve, ladle and net having a mesh diameter of 0.5 mm. The samples were killed in 70% alcohol solution and then the clayey and muddy substance on their surfaces was brushed off with a small paint brush in the laboratory.

Samples were examined using a Nikontype SMZ-U stereo microscope. Photo of *D. toledoi* (Fig. 2) was taken with Canon EOS 70D DSLR digital camera attached to a microscope Leica Z16APO with a ring LED light using EOS Utility software.

Fig. 2. Dorsal view of *Deronectes toledoi*.

Water sampling and analysis

Dissolved oxygen (mg O_2 L^{-1}), conductivity (±1 μS cm^{-1}), water temperature (°C), and pH were measured *in situ* using portable meters (YSI Model 52, Ohio, USA; YSI Model 30 salinometer; Orion Model 420A pH meter, respectively).

To determine the general chemical characteristics of the brook, such as Anions (NO_2-N, NO_3-N, SO_4, PO_4, F, Cl) and cations (Na, K, Mg, Ca, NH_4-N), water samples were collected monthly from the sub surface in acid-washed polyethylene bottles. In laboratory, anions and cations of the water were analyzed by using Dionex ICS 3000 and Dionex ICS 1000 model devices (Ion Chromatography System), respectively.

Diversity analyses

For the whole community, we calculated the Shannon-Wiener's diversity index (H), evenness (E) and species richness (D) according to giving formulas below.

Shannon-Wiener's diversity index (H):

H = -SUM[(pi) * ln(pi)]

SUM = Summation

pi= Number of individuals of species i/total number of samples

S = Number of species or species richness

E= Eveness=H/Hmax

Hmax = Maximum diversity possible

Species richness (D):

$$D = s/\sqrt{N}$$

where s equals the number of different species represented in our sample, and N equals the total number of individual organisms in our sample.

Statistical methods

Data were log10 (x+1) transformed, if necessary, to help meet the assumptions of normality. Statistical analyses were performed with R (R, 2008). One way ANOVA was conducted to test the seasonal differences between measured water quality parameters.

Redundancy analysis (RDA) and Monte Carlo tests (499 permutations) were performed to identify the relationships between environmental variables, months and the aquatic Coleoptera community. Abundance value of the species and measured values of the environmental variables were used in the ordination analysis. Before running RDA, the data were tested with detrended correspondence analyses (DCA) to evaluate the suitability of the data for RDA (ter Braak, 1989). In order to determine the environmental variables explaining the maximum variation in the species data, highly collinear environmental variables were identified by their high variance inflation factors (VIF). Variables with VIF >20 were excluded from the environmental dataset. Monte Carlo permutation tests were applied in order to test for the significance of each environmental variable used in the ordination analyses. A series of RDA ordinations with forward selection were run to determine the subset of significant environmental parameters. Environmental variables that not explain a significant proportion of species variance after Monte Carlo permutations ($p < 0.05$; 999 random permutations) were excluded from the ordination analyses. The three most influential variables for species assemblages were displayed in RDA biplot.

RESULTS

Physicochemical conditions of the stream

Monthly fluctuations of physico-chemical parameters in the breeding habitat were given in Table 1. Water temperature ranged from a minimum of 2.9 °C in April to a maximum of 20.2 °C in May. Water temperatures were significantly higher in summer than the spring and autumn (p: 0.02 and p: 0.01, respectively). Dissolved oxygen concentrations ranged between 8.5 and 11.7 mg/l during the study period. Values of pH stayed approximately constant during the whole period and varied between 8 and 8.43. Conductivity of the habitat ranged between 345 and 459 µS/cm and there were no significant seasonal differences for the conductivity values.

Magnesium concentrations ranged between 3.01 and 8.62 mg/L and its concentrations were significantly higher in autumn than the other seasons (p: 0.01 and p: 0.03, respectively). Calcium concentrations ranged between 58.88 and 188.33 mg/L and its concentrations were significantly higher in autumn than the other seasons (p: 0.01 and p: 0.03, respectively).

Ammonium and nitrite concentrations did not differ between seasons (Table 1). Nitrate concentrations were significantly higher in autumn than the spring and summer (p: 0.02 and p: 0.01, respectively) and ranged between 0.39 and 7.41 mg/L during the study period.

Phosphate values were too low to be measured, except in autumn. Values of chlorine and flour were low and their concentrations were not significantly different between seasons. Concentrations of potassium, sodium and sulphate were not significantly different between seasons.

Habitat waters were determined as class I waters with regard to the parameters, except nitrogen parameters (ammonium, nitrite and nitrate) which were higher in rainy months.

Community structure, diversity and dynamics

Monthly abundance and composition of the aquatic Coleoptera community of the brook were given in Table 2. We could not find any specimen in March, April and November samplings. The aquatic Coleoptera community in the creek included three families. The most abundant family was Dytiscidae, followed by Hydrophilidae, while family of Haliplidae was only observed in July (Table 2). The number of coexisting species during the study period ranged from a maximum of six species in July and August, to a minimum of two species, in September (Table 2). In total, 19 *Deronectes toledoi* specimens were collected between March and November 2009 period (Table 2). The most of the individuals were identified in July (n=6) while no individuals were identified in March, April and November.

Table 2. Monthly abundance and composition of the aquatic Coleoptera community of the brook.

Family	Species	May	June	July	August	September	October
HYDROPHILIDAE	*Laccobius* sp.	3		2	4		
	Helophorus sp.	2					
	Enochrus sp.				1		
	Hydrobius sp.			2			
DYTISCIDAE	*Agabus paludosus*	1					
	Laccophilus minutus			1			
	Ilybius fuliginosus			2	2	1	
	Bidessus unistriatus				3		
	Deronectes toledoi	3	5	6	3	1	1
	Hydroporus thracicus				2		
HALIPLIDAE	*Haliplus* sp.			2			

In terms of diversity dynamics, the Shannon-Wiener index (H) started to increase gradually to a maximum in August and afterwards it decreased sharply (Table 3). The evenness presented slight fluctuations but nearly same during the study period (Table 3). Species richness (D) was low during the study period except July and August (maximum Species richness, Table 3). There was a negative correlation between the precipitation and Species richness ($r = -0.843$, p: 0.017) and positive correlation between air temperature and Species richness ($r = 0.64$, p: 0.05).

Table 3. Shannon-Wiener diversity index (H), evenness (E) and Species richness (D) of the aquatic Coleoptera community in the brook throughout the study period. NA: Not applicable/cannot be calculated.

	Shannon-Wiener (H)	Evenness (E)	Species Richness (D)
May	1.31	0.94	4
June	0	NA	1
July	1.64	0.92	6
August	1.72	0.96	6
September	0.68	0.98	2
October	0	NA	1

Relationship between environmental parameters and macroinvertebrate community

DO_2, Ca and water surface temperature were displayed in RDA biplot since they were the three most influential variables for species assemblages. First two axis (axis 1: 43 %, axis 2: 39 %) of RDA gave an 82% correlated relation between species and environment (Fig. 3). After the forward selection used with the Monte Carlo Permutation test applied, only three of physicochemical parameters were found to be significant ($p<0.05$) on the ordination of RDA. These are dissolved oxygen, calcium and water surface temperature. Among them, surface water temperature and calcium parameters are highly correlated with axis one. While surface water temperature gave a strong negative correlation, Calcium gave a strong positive correlation. Only the dissolved oxygen gave a positive correlation with the second axis. It is seen that the distribution of taxa is generally on the second axis. Among the taxa, it is seen that *D. toledoi* appears to be related with surface water temperature rather than axis two.

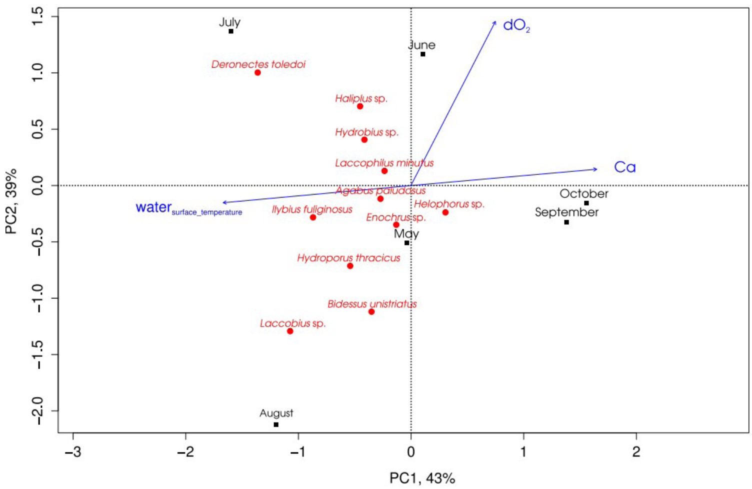

Fig. 3. Redundancy analysis plot of insect communities in months affected by changes in dissolved oxygen (DO_2), water surface temperature and Calcium (Ca).

DISCUSSION

Correlational and multivariate ordination statistical techniques are usually used to identify key environmental conditions within which the species is present based on environmental data from available occurrence records (Ter Braak, 1987). We applied RDA to understand the causes of the distribution of *Deronectes toledoi* since predicted distributions reflect those areas in which a species is predicted to occur, based on environmental conditions in known localities (Soberon and Nakamura, 2009). Our results showed that the realized distribution of a species was controlled largely by environmental factors (82 %). According to the RDA ordination, it might be concluded that *D. toledoi* requires some different environmental conditions that the taxa they were together with such as Hydrophilidae and Haliplidae. Water surface temperature seemed to be the most important environmental factor influencing the occurrence of species. The thermal limits of *Deronectes toledoi* would be the advantage to compete with other diving beetles in the area. We could not collected *Deronectes toledoi* members from the creek during winter months. This might be explained as follows; individuals of this species may also overwinter on land, as observed in other dytiscids (Galewski, 1971). Although *Deronectes toledoi* is an aquatic animal, and maximum and minimum water temperatures in the creek were less extreme than air temperature, they might have strategies to avoid exposure to potentially harmful low temperatures, as it seems to be the case in other insects (Block, 1990). It is known that

Deronectes species spend part of their life cycle (pupal stage and the early adult stages) on land as other dytiscids (Galewski, 1971; Sanchez-Fernandez, 2012). In *Deronectes*, these stages take place mainly in spring and early summer, when air temperatures are relatively high (Sanchez-Fernandez *et al*. 2012). These might be the reasons why we observed more adult individuals of in summer months.

Since there were no polluting sources around the habitat and it was away from residential areas, water ionic concentrations of the creek were low. The reason why some parameter, were high in March in the habitat could be related to the material, carried into the habitat melting by snow. Basic reason of an increase of most physico-chemical parameters in autumn can be related to increasing surface runoff with heavy precipitation. The low species richness in the habitat might be related to these low ionic concentrations since some studies establish that stream water of very low ionic concentration has a restricted flora and fauna, in both abundance and species richness (Allan and Castillo, 2007).

Increasing concentrations of magnesium and calcium in autumn could be related with increasing weathering of rocks due to the increasing current speed of river in heavy precipitation. In terms of diversity dynamics, maximum Shannon-Wiener index (H) maximum Species richness (D) were observed in August with higher air and water temperatures and lowest precipitation. Precipitation may be causing the low species diversity and preventing diving beetles from inhibiting stony or gravelly part of the creek. Increasing current might be preventing the maturation of the diving beetles in the habitat and thus we could not come across any beetles in autumn. *Deronectes toledoi* might be more tolerant to precipitation since it was the only species occuring in autumn months. However, higher temperature in summer provided higher species diversity and showed that temperature is important factor in determining assemblage structure of diving beetles.

Deronectes toledoi was not a dominant species since the evenness presented slight fluctuations but it was nearly the same during the study period. However it is a more tolerant species than other diving beetles of the creek since it was the only occurring species in autumn. Although calcium is the fifth most abundant natural element in the world and it is required by all plants and animals, often in large quantities (Cairns and Yan, 2009), our results showed that calcium demand of *Deronectes toledoi* was not high and calcium was not a limiting factor for both *Deronectes toledoi* and other aquatic Coleoptera in the creek.

Deronectes toledoi and other aquatic Coleoptera of the creek were negatively correlated with dissolved oxygen. It might be indicating that their oxygen demand was low and higher oxygen concentrations were observed in autumn with low water temperature, higher precipitation and higher current.

CONCLUSIONS

Due to the limited area for studying an endemic species and of course, rarity of the taxon the interpretation of statistical analyses was very difficult. However, our results might be very important in terms of being the first and providing data for future studies. Since species could be only sampled from one habitat in our study, we cannot explain accurately the effect of water parameters on the population density of the sampled species. With this study, both some data about bio-ecology of some aquatic Coleoptera and the species diversity of the streams in highland area were obtained. Further multidisciplinary studies of the biological diversity in streams, which are important for natural conservation, are necessary to understand the ecology of rare and endemic species.

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