http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 35(1): 55-61 (2018)

Su Ürünleri Dergisi (2018)
DOI: 10.12714/egejfas.2018.35.1.10

RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

First observation of the zebra mussel (*Dreissena polymorpha* (Pallas, 1771)) on the narrow-clawed crayfish inhabiting in some water sources of Turkey

Zebra midyesinin (*Dreissena polymorpha*'nın (Pallas, 1771)) Türkiye'nin bazı su kaynaklarında yaşayan dar kıskaçlı kerevitler üzerinde ilk olarak gözlenmesi

Selçuk Berber* ● **A. Suat Ateş** ● **Seçil Acar**

Çanakkale Onsekiz Mart University, Faculty of Marine Sciences and Technology 17100 Çanakkale, Turkey
** Corresponding author: selcukberber@comu.edu.tr*

Received date: 19.09.2017 *Accepted date: 29.12.2017*

How to cite this paper:
Berber, S., Ateş, S. & Acar, S. (2018). First observation of the zebra mussel (*Dreissena polymorpha* (Pallas, 1771)) on the narrow-clawed crayfish inhabiting in some water sources of Turkey. *Ege Journal of Fisheries and Aquatic Sciences,* 35(1): 55-61. doi:10.12714/egejfas.2018.35.1.10

Abstract: The zebra mussel, *Dreissena polymorpha* (Pallas, 1771) is considered as a harmful invasive epibiont species for hydroelectric and nuclear power plants as it reduces or blocks water flow in the plant systems. Although *D. polymorpha* is reported that it cleans the water, increases water visibility, and filters out pollutants, it has likewise negative impacts on the population and size of some fish and aquatic species. In the present study, zebra mussels were observed for the first time. On the narrow-clawed crayfish living in some water sources in Turkey. Specimens were collected from two natural lakes (Çıldır Lake, Eğirdir Lake) and five ponds (Altınyazı Dam Lake, Keban Dam Lake, Küçükçekmece Lake, Karpuzlu Dam Lake, Kadıköy Dam Lake) in Turkey. Attachments of the zebra mussel to the different body parts of the narrow-clawed crayfish were documented in the present study. Cochran's Q test results showed that the numbers of mussels clinging to the different parts of the crayfish varied (P=0.000) (P <0.001). The difference between the holding regions of zebra mussels on crayfish specimens may cause some adverse effects on the host. Particularly the intensive grip on the carapace partially obstruct the movement, feeding, mating, avoiding predators, and shelter. mussel individuals in the pleopodal region may have difficulty holding and transporting eggs. This study is the first report about the occurrence of *D. polymorpha* on *Astacus leptodactylus* in Turkish waters.

Keywords: *Dreissena polymorpha, Zebra mussel, Astacus leptodactylus, body colonization, Turkey*

Öz: Zebra midyeleri, *Dreissena polymorpha* (Pallas, 1771) hidroelektrik ve nükleer güç sistemlerinde su akışını engellediğinden zararlı bir istilacı epibiont türü olarak kabul edilir. *D. polymorpha* suyun temizlenmesi, su görünürlüğünün arttırılması ve kirleticilerin filtrelenmesi olarak rapor edilmesine rağmen, bazı balıkların ve sucul türlerin popülasyonu ve büyüklüğü üzerinde olumsuz etkilere sahiptir. Bu çalışmada, zebra midyesi Türkiye'deki bazı su kaynaklarındaki tatlısu ıstakozu üzerinde ilk defa gözlemlenmiştir. Bireyler Türkiye'deki iki doğal göl (Çıldır Gölü, Eğirdir Gölü) ve beş göletten (Altınyazı Baraj Gölü, Keban Baraj Gölü, Küçükçekmece Gölü, Karpuzlu Baraj Gölü, Kadıköy Baraj Gölü) toplanmıştır. Bu çalışmada, kerevitlerin farklı vücut bölümlerine zebra midyesinin tutunması belgelenmiştir. Cochran's Q test sonuçları; kerevitin değişik bölümlerine tutunan midye sayılarının farklılık gösterdiğini ortaya koydu (P=0.000) (P <0.001). Zebra midyelerin tatlısu ıstakozlarının üzerinde tutunma bölgeleri arasında farklılığın tespit edilmesinin konakçı açısından bazı olumsuzluklara neden olabileceği düşünülmektedir. Özellikle carapax bölgesinde yoğun tutunmaların; hareket (beslenme, çiftleşme, predatörlerden kaçınma ve barınma). Pleopodal bölgedeki midye bireyleri ise yumurta tutunumu ve taşınımını zorlaştırabilir. Bu çalışma Türkiye sularındaki *Astacus leptodactylus* üzerinde *Dreissena polymorpha*'nın varlığı ile ilgili ilk rapordur.

Anahtar kelimeler: *Dreissena polymorpha, Zebra midyesi, Astacus leptodactylus, vücut kolonizasyonu, Turkey*

INTRODUCTION

Invasions and their negative impact on native communities are considered as important threats to biodiversity (Geiger et al. 2005). Invasive species may change the behavior and habitat use of native species. Population structure, distribution and abundance of the species are affected by invasive species (Simon and Townsend, 2003). Zebra mussel, *Dreissena polymorpha* (Pallas, 1771) is an invasive Ponto-Caspian bivalve and has invaded the European's river and channel systems during the last two centuries (Gonçalves et al. 2013). It has been introduced to the northwestern Russia, the southern Scandinavia, Britain, Ireland and the north America (Gonçalves et al. 2013; Minchin and Rosenthal, 2002) and found the east into the western Asia and the south into Turkey (Mackie et al. 1989). These invasions cause dramatic changes on benthic ecology and have both negative and positive effects on benthic ecosystem. Zebra mussel increases colonies of gastropod, but

limits their body size. *D. polymorpha* has positive effect on deposit feeding taxa and negative effect on filter-feeding taxa (Ward and Ricciardi 2007).

Environmental and anthropogenic factors affect the spread of *D. polymorpha* in a new area. Water quality, alkalinity and high levels of calcium in fresh water increase the populations of zebra mussel juveniles. The levels of pH, temperature, and potassium in water positively affect colonization and population structure of the zebra mussel (Stier et al. 2001). The narrow-clawed crayfish, *Astacus leptodactylus* is a suitable substrate for the settlement of fouling organisms. Livings such as cyanobacteria and chlorophyta, ciliata, corixid eggs, mites, ostracods, oligochaetes, polychaetes, rhabdocoel flatworms, rotifers, Argulus eggs, bryozoans, and zebra mussels are settle down on crusts of freshwater crayfish (Alderman and Polglase 1988; Amato, 2001; Brazner and Jensen 2000; Cannon and Jennings 1987; Ďuriš et al. 2007; Edgerton et al. 2002; Lamanova, 1971; Romero and Jiménez 2002; Morado, 1995; Harlıoğlu, 1999; Sprague and Couch, 1971; Şaşı and Berber, 2005; Quaglio et al. 2006). The zebra mussels modify the natural movement of crayfish and they may affect the anthropogenic structure (Ahne, 1985; Feist et al. 2001; Molloy et al. 1997; Mühlegger et al. 2009). Due to the zebra mussels are colonized on crayfish, the specimens of crayfish spend more energy. These factors (feeding, nursing, mating, molting etc.) lead to a reduction in life chances (Brazner and Jensen 2000). This study was aimed to describe the effects of microhabits on the crusts of *A. leptodactylus* specimens found in two lakes and five dam lakes in Turkey.

MATERIALS AND METHODS

Sampling stations

A total of 228 specimens of *A. leptodactylus* were collected August 2009 - December 2009 from two lakes (Eğirdir Lake (38°3'24"N-30°51'58"E), Çıldır Lake 41°1'20"N-43°13'55"E) and five dam lake (Altınyazı Dam Lake (41°3'28"N-26°35'27"E), Keban Dam Lake (38°50'39"N-39°10'30"E), Küçükçekmece Lake (41o00'59"N-28o74'89"E), Karpuzlu Dam Lake (40°49'58"N-26°17'38"E), Kadıköy Dam Lake (40°47'38"N-26°46'26"E)) located of Turkey. Crayfish specimens were sampled using the single-entry two pints fyke nets of 34 mm mesh size by researchers. Sampled crayfish were separated to sex. Then, the body parts of crayfish were divided according to the zebra mussel's attachment. The zebra mussels were observed in the different parts of crayfish were photographed. It was observed whether the individuals of *D. polymorpha* removed from holding parts caused any damage on crusts of *A. leptodactylus* specimens. All crayfish specimens with the zebra mussels were proportionally recorded. Cochran Q test and MDS (Multidimensional Scaling Analysis) were applied to determine the chances in the cling aspects of *D. polymorpha* on the crusts of *A. leptodactylus*.

The Q statistic is distributed approximately as chi- square with (a-1) degree of freedom (Zar, 1999).

Cochran Q-test:

Test statistic for Cochran Q test:

$$Q = \frac{(a-1)\left(\sum_{i=1}^{a} G_i^2 - \frac{\left(\sum_{i=1}^{a} G_i\right)^2}{a}\right)}{\sum_{j=1}^{b} B_j - \frac{\sum_{j=1}^{b} B_j^2}{a}}$$

Where; a is the number of group, b is the number of block, Gi is the sum of the 1's in group I, Bj is the sum of the 1's in block j

RESULTS

A total of 228 individuals of crayfish individuals were captured from the different locations in Turkey. The body length range of the crayfish was between 99.28 and 146.14 mm. The mean body length of the crayfish is 138.02±2.063 mm in Altınyazı Dam Lake, 118.2±4.56 mm in Keban Dam Lake, 129.06±5.68 mm in Çıldır Lake, 115.28±1.61 mm in Küçükçekmece Lake, 116.39±4.44 mm in Eğirdir Lake, 133.46±2.68 mm in Karpuzlu Dam Lake and 125.72±2.61 mm in Kadıköy Dam Lake. Although the zebra mussels prefer the different body parts of crayfish, the carapace is the most attached part with a ratio of 25.6%. Totally, 28 specimens of the zebra mussel were observed on the carapace. The lowest rate (0.73%) was recorded on the oviducts of crayfish. Only one individual clung to the oviduct. The body lengths of *D. polymorpha* specimens clunged to the bodies of crayfish are mostly less than 5 mm (Table 1).

Table 1. The body part preference on the body of crayfish by *D. polymorpha*.

Sampling sites	N	N'	M	F	C	R	AD	CV	An	CD	T	P	O
Altınyazı Dam Lake	18	3	3	-	1	1	1	1	0	2	1	1	0
Keban Dam Lake	51	3	3	-	1	0	0	0	1	3	0	1	0
Çıldır Lake	34	3	3	-	2	1	1	0	1	1	0	1	0
K.Çekmece Dam Lake	26	12	2	10	5	5	5	0	4	8	7	0	0
Eğirdir Lake	48	1	-	1	1	1	0	0	1	0	0	0	0
Karpuzlu Dam Lake	24	13	10	3	3	1	3	2	0	3	6	10	0
Kadıköy Dam Lake	27	14		9	4	0	7	4	1	11	1	0	1
Total	228	49	26	23	17	9	17	7	8	28	15	13	1

N: number of crayfish examined, N': number of crayfish carrying *D. polymorpha*, M: Male, F: Female, C: Chela, R: Rostrum, AD: Abdomen, CV: Carapace ventral, An: Antenna, CD: Carapace dorsal, T: Telson, P: Pleiopod, O: Oviduct

Crayfish specimens show reactions with respect to the change of the body regions invaded by the zebra mussels (Fig. 3). Holding locations on the crayfish by the zebra mussels are no accidental for both sexes of *A. leptodactylus*. According to the results of the MDS analysis, sexuel difference in crayfish have a decisive effect about holding of zebra mussels. The body length of crayfishes in both sexes is decisive in choosing the region to be attached by *D. polymorpha* (Fig. 1, 2).

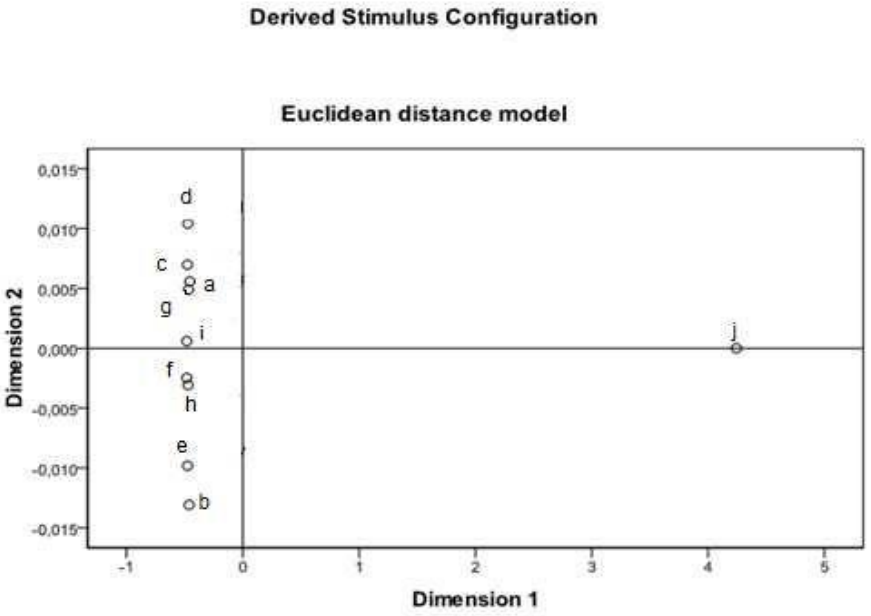

Figure 1. Multidimensional scaling analysis for female crayfish, a: carapace dorsal, b: abdomen, c: antenna, d: rostrum, e: carapace ventral, f: oviduct. g: chela, h: telson, I: pleopod; j: length.

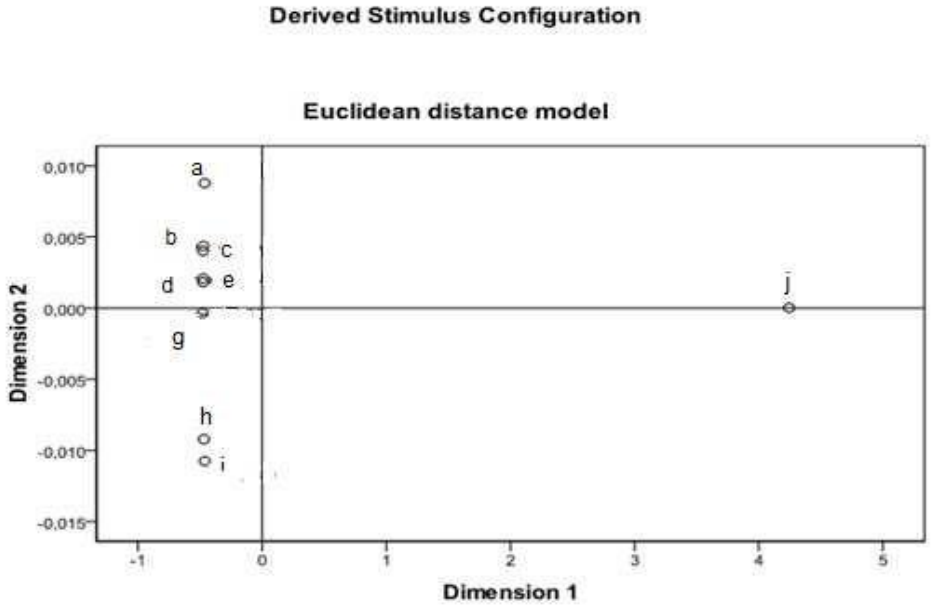

Figure 2. Multidimensional scaling analysis for male crayfish, a: carapace dorsal, b: abdomen, c: antenna, d: rostrum, e: carapace ventral, g: chela, h: telson, i: pleipod, j: length.

Figure 3. Zebra mussel specimens on the various body parts of crayfish, *A. leptodactylus*.(A, C, D, G: on carapace dorsal, B, E: on eyes, F: on carapace ventral and pleiopod, H: on cheliped)

DISCUSSION

D. polymorpha composes dense populations on any available hard substrate. Its veliger larvae settles predominantly on shells or near older zebra mussels (Griffiths et al. 1989). The specimens of *D. polymorpha* can also settle on a crayfish exoskeleton (Rogers et al. 2003). The first observation of *D. polymorpha* as host on crayfish was given by Laurent and Suscillon (1962) from male specimens of *D. polymorpha* on *O. limosus* observed in France. This phenomenon was confirmed for the Lake of Geneva (Lac Léman) by Laurent (1994) on *O. limosus*. Lamanova (1971) reported the zebra mussels on crust of crayfish, *Astacus leptodactylus cubanicus* co-inhabiting to the original distribution area of the zebra mussel.

Smietana (1996) reported the occurrence of the zebra mussels on *O. limosus* in the Dąbie Lake (Poland). Lajtner et al. (2005) reported the specimens of *D. polymorpha* attached to the carapace of crayfish, *O. limosus* in Croatia. While rare, a similar phenomenon has been observed in Lake Michigan (the North America) (Brazner and Jensen 2000) and the individuals of *D. polymorpha* occurred on the body of the rusty crayfish, *Orconectes rusticus*.

D. polymorpha was introduced to Czech waters via two directions (by the Danube and Morava rivers) (Beran, 2002). Petrusek *et al.* (2006) carried out a study on the invasion of *O. limosus* by *D. polymorpha* in about 60 localities of Czech Republic in 2003-2004. According to Petrusek et al. (2006), the carapace of specimens of crayfish were colonized by mussels and this manner shows that this phenomenon is rather rare. Besides, this unusual situation clarifies the lack of available hard substrates for larval veliger settlement, although other environmental variables such as nutrients, water temperature, and chemistry measured are optimal for the zebra mussel population. The high calcium ion concentration, pH, summer temperatures up to 25°C, absence of spring algal bloom and round-year clean water indicate moderate tropic relations. All these environmental variables are well comparable with existing knowledge on *D. polymorpha* requirements (McMahon, 1996; Bowman et al. 1998; Toomay et al. 2002).

The microhabitats used by the zebra mussel for colonization are interesting. Brazner and Jensen (2000) refer that *D. polymorpha* mostly colonized the carapace of *O. rusticus* rather than the parts of the body such as chelae, telson, and uropod. Ďuriš et al. (2007) reported that the mussel specimens of one-year old were concentrated mainly on the anterior dorsal surface of the abdomen, although some remained on both the ventral abdomen and telson, and the anterior dorsal of cephalothorax.

Due to the zebra mussels colonize on crayfish, crayfish specimens spend more energy. Besides, crayfish can be easily recognized by the predators (Brazner and Jensen 2000). Moreover, *D. polymorpha* clinked to the different parts of crayfish inhibit the movement, sight, prey capture, reproduction, and molting ability (Lamanova, 1971; Bauer, 1989; Brazner and Jensen 2000).

This study showed that the females of crayfish invaded by *D. polymorpha specimens* have no fertilized eggs and this is another negative effect. On the other hand, the zebra mussels prefer especially the bodies of crayfish on soft-bottoms (Ďuriš et al. 2007). Thus, due to erosion in inland water resources the bottom structure change and it can be soft (Quinn and Janssen 1989).

Toomey et al. (2002) reported that the small (5-10 mm) specimens (%55 of total population) of the zebra mussel are more navigate in their environment when compared to bigger individuals (10-20 mm). Toomey et al. (2002) concluded that the reason of this is the small mussels produce the smaller byssus and these small specimens leave more often from their substrate. In the present study it was recorded that the most of *D. polymorpha* clinked to crayfish in this study are small.

According to previous studies, the most of *D. polymorpha* attached to the crayfish had a length that is less than 5 mm and these specimens were younger than 1 year old (Ackerman et al. 1994; Ďuriš et al. 2007).

When the regional distributions of the species are considered approximately 50% of crayfish captured in Kadıköy Dam Lake, Karpuzlu Dam Lake, and Küçükçekmece Dam Lake have zebra mussels on them. Due to intensive fisheries activities in the areas cited, we think that larvae of Zebra mussels may be transported to near lake systems by fishing gears. In Turkey, transport of fishing gears used in inland water fishery is frequently observed between the lakes, ponds and reservoirs. This manner facilitates the transport of many disease agents and fouling organisms between locations. Also, uncontrolled fish and freshwater lobster infestations can cause similar results. Especially *Dreissena polymorpha* can stay alive for a long time outside of water (Altınayer et al., 2001). In particular, the research and fishing activities carried out by fishermen in the areas close to each other in Thrace Region have facilitated the transport of *Dreissena polymorpha*.

Our statistical results shows, that difference of holding regions on crayfish specimens is so important, regarding the cling ability of the mussels on the body parts of the crayfish. Furthermore, the clinging regions of the mussels on the crayfish's body sections are no accidental. The females of crayfish exhibit mostly the keeping behavior during their nest periods and are less active. Therefore, the zebra mussels have a better hold to the female crayfish. Differences between the sticking places of the zebra mussels were also observed (Duris et al., 2007). Ďuriš et al. (2007) stated that these differences are based on the parts cited are easily cleaned by individual crayfish.

Although the zebra mussels are consumed by crayfish, they have many unfavorable effects on crayfish. Consequently, the similar studies on invasion of Zebra mussel in various

geographical areas of Turkey should be carried out to have more detailed information on the subject in future.

Studies on its distribution and invasion should be increased to have more information about ecological effects of *Dreissena polymorpha*. In DNA studies, the origins, differences and similarities of the populations at locations can be determined (Rohfritsch et al., 2013). Recently, it has been determined which populations are present in geographical areas invaded by *D. polymorpha*. In addition, it can be determined from which gene pool these populations are distributed (Lalias et al., 2015; Anglès d'Auriac et al., 2017).

Thanks to the results of such studies, more knowledge is available about limiting effects of characteristics such as growth and reproduction of Zebra mussels on crayfish populations and interaction of species with each other. This present work deals with the presence of Zebra mussels on crayfish specimens.

CONCLUSION

Because of its role in the food chain, *Dreissena polymorpha* has positive effects on feeding, growing and population structure of many species. Yet, *D. polymorpha* is important to increase water clarity because of its filtration feature. Due to their high adaptation to environmental conditions and rapid reproduction, *D. polymorpha* specimens have very negative effects on other species in reservoirs. For that reason, an action plan on this species which causes billions of dollars of damage in the world should be prepared. Particularly, the methods (biological, chemical and physical) blocking the distribution of *D. polymorpha* should be determined. Furthermore, informative studies on reservoirs should be made.

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