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Invasive freshwater jellyfish *Craspedacusta sowerbii* (Lankester, 1880) in Turkey: New locality record and habitat limnoecology, with an overview of distributional data in the Middle East and Balkans

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Abstract

A new locality for the invasive freshwater jellyfish (*Craspedacusta sowerbii* Lankester, 1880) was found during a study conducted in a mesotrophic dam lake (Ürkmez Reservoir, western Anatolia, Turkey). The study was focused on the limnological characteristics of the reservoir and conducted at monthly intervals between March 2014 and February 2015. Some limnological characteristics (physicochemical parameters, phytoplankton composition, and trophic status) of the investigating area are presented. In August and September 2014, jellyfish specimens were observed just beneath the surface (3-4 spec/m^2). In the remaining period of the study, no jellyfish specimens were found in the limnetic zone of the reservoir. *C. sowerbii* has been rarely observed in Turkish freshwaters. The present record is the westernmost point of its distribution in Turkey. An overview of its distribution in South-Eastern Europe and the Middle East, and a map showing the actual distribution in the mentioned area was given.

Keywords: invasive species, freshwater jellyfish, reservoir, geographical distributional data

Türkiye'deki istilacı tatlısu medüzü *Craspedacusta sowerbii* (Lankester, 1880): Yeni lokalite kaydı, habitat limnoekolojisi ve Orta Doğu ve Balkanlar'daki dağılımı

Özet

Mezotrofik bir baraj gölünde (Ürkmez Baraj Gölü, batı Anadolu, Türkiye) yapılan çalışma esnasında istilaci tatlısu medüzü (*Craspedacusta sowerbii* Lankester, 1880) için yeni bir lokalite bulunmuştur. Çalışma baraj gölünün limnoekolojik özellikleri üzerineydi ve Mart 2014 ile Şubat 2015 tarihleri arasında aylık olarak yapıldı. Çalışma yapılan habitatın bazı limnolojik özellikleri (fizikokimyasal parametreler, fitoplankton kompozisyonu ve trofik durum) sunulmuştur. Ağustos v Eylül 2014 tarihlerinde medüz bireyleri yüzeyin hemen altında olacak şekilde gözlemlenmişlerdir (3-4 birey/m^2). Çalışmanın geri kalan dönemlerinde baraj gölünün limnetic bölgesinde medüz bireylerine rastlanılamamıştır. *C. sowerbii* Türkiye'nin tatlısularında nadir görülen bir türdür. Mevcut kayıt, türün Türkiye dağılımndaki en batı noktayı teşkil etmektedir. Çalışmada ayrıca, türün Güneydoğu Avrupa ve Orta Doğu'daki dağılımı gözden geçirilmiş olup, türün belirtilen bölgelerdeki güncel dağılımını gösteren bir harita sunulmuştur.

Anahtar kelimeler: istilacı tür, tatlısu medüzü, baraj, coğrafik dağılım datası

INTRODUCTION

More than 20 freshwater jellyfish species were identified worldwide (Jankowski et al., 2008). Among them, *Craspedacusta* and *Limnocnida* are the two main freshwater Cnidarian genera, which are originated from Asia and both of them produce medusa (Arbačiauskas and Lesutienė, 2005). Although all of the species within the genus *Craspedacusta* have a limited distribution area, which covers the Asian tropical and subtropical freshwater parts (mainly China and Japan), only *Craspedacusta sowerbii* (Lankester, 1880) distributes in an extended large area (Jakovčev-Todorović et al., 2010). The exact number of the valid species belong to the genus *Craspedacusta* is not clear in the literature [three species reported by Jankowski (2001); or five species given by Boulenger and Flower, (1928)]. It has a worldwide distribution and inhabits almost all types of freshwater bodies of big islands and all of the continents except Antarctica (Dumont, 1994). There are numerous records on the occurrence of this jellyfish both in natural (lakes, ponds, and streams) and artificial (reservoirs, pools) freshwater bodies of temperate to subtropical regions worldwide (Duggan and Eastwood, 2012).

In a comprehensive study on the world distribution of *C. sowerbii,* Dumont (1994) mentioned the presence of this species at two localities in Turkey. The first one is an aquarium occurrence in İstanbul and the other one is a locality in the Fırat-Dicle region (probably Keban Reservoir). Later, the species was recorded from an artificial water body located in the Büyük Menderes River Basin (Topçam Reservoir) (Balık et al., 2001). Then, *C. sowerbii* was reported from the Kozan and Kralkizi dam lakes (Bozkurt, 2004; Bekleyen et al., 2011). A few years ago, two new localities were reported which are Sapanca Lake and Karacaören I Dam Lake (Akçaalan et al., 2011; Gülle et al., 2014). Lake Sapanca is the first and single habitat of this species from a natural lake in Turkey until now. The latest paper on the occurrence of *C. sowerbii* was about the existence of this unique species at Ula Pond, Muğla Province (Gülşahin, 2017).

In this paper, a) we recorded a new locality for the distribution of this jellyfish species from Turkey, b) reported selected limnoecological features of the new locality for the first time, c) and overviewed the geographical distribution of *C. sowerbii* in SE Europe and the Middle East.

MATERIALS and METHODS

Ürkmez Reservoir has been established for providing irrigation and drinking water requirements of the neighboring settlements between 1985 and 1989 on the Küçük Menderes River. It has about 1 km^2 surface area and is located in Seferihisar District, İzmir Province, Turkey (Figure 1). Two sampling points (38° 05' 42"N - 26° 57' 22"E and 08° 06' 02"N - 26° 57' 24"E) were chosen to measure the environmental characteristics and conduct a limnological study in the reservoir. Water samples and biological materials were collected between March 2014 and February 2015 at monthly intervals using a 2 L Hydrobios water sampler and plankton net (60µm mesh size). The biological materials were primarily fixed with Lugol's iodine solution for a short time while the permanent preservation was made with 4% formaldehyde.

Transparency of the water column was measured by Secchi-disk (30 cm Ø). Water temperature, pH, dissolved oxygen, salinity, and conductivity were measured by a multiparameter (model WTW 3420i SET). Other chemical analyses and chlorophyll-a were performed in the laboratory following standard methods and using a spectrophotometer (model Hach Lange Dr 6000-spectrophotometer, APHA, 1980).

The observation of each phytoplankton species was presented as percent frequency in monthly intervals and relative abundance was calculated according to Utermöhl's method (Sournia, 1978). Trophic State Index (TSI) was calculated from the values of Total Phosphorus (TP), Secchi Depths, and Chlorophyll *a* (Chl-*a*) to determine the eutrophic level of the reservoir (Carlson, 1977).

To find out the current distribution of *C. sowerbii* in South-Eastern Europe and the Middle East, the relevant literatures were examined and each record was mapped (Figure 1). Taxonomic identification of the medusa was carried out morphologically according to Jankowski (2001) under an Olympus stereomicroscope and light microscope. The individual density was calculated by snap observations on an area of approximately one square meter in situ.

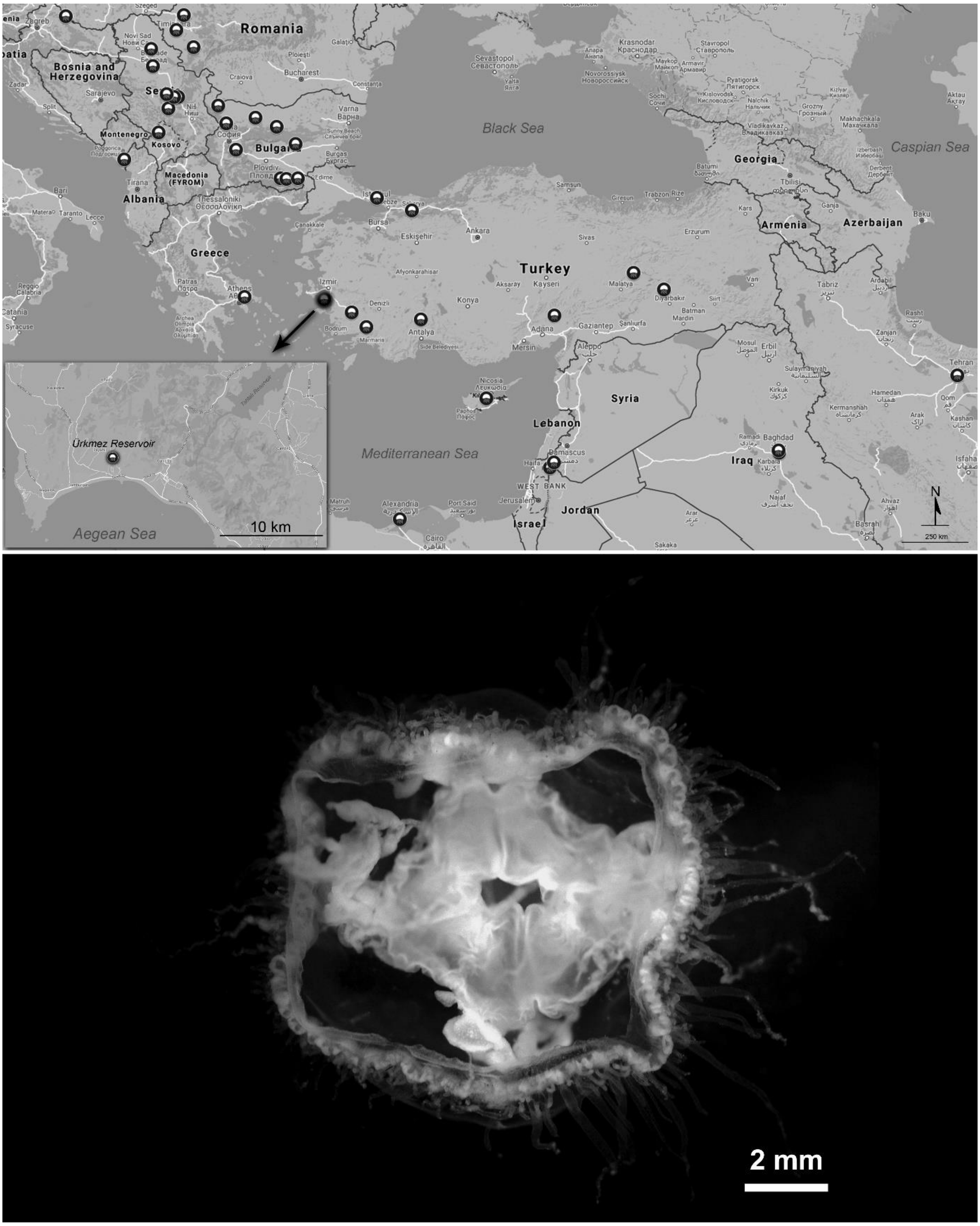

Figure 1. Distribution of the *C. sowerbii* in SE Europe and the Middle East (Google n.d., 2019) and the photo of a sampled specimen of *C. sowerbii* (Photograph by Semih Engin)

RESULTS

C. sowerbii was recorded for the first time in Ürkmez Reservoir and Basin of Küçük Menderes River. The reservoir is the westernmost point in the distribution area of *C. sowerbii* in Turkey. The specimens were observed during the summer period (August and September) of 2014. The medusa density was about 3-4 ind. /m^2 at both of the sampling stations. In the remaining period of the study, no *C. sowerbii* specimens were found in the pelagic zone of the reservoir.

The maximum depth of the two stations showed significant fluctuations throughout the year. The maximum depths of both stations were measured in November (23 m and 18 m) while the minimum of the first station was in July (10 m) and that of the second one was in October (4 m). The Secchi depths of the stations were maximum in May and minimum in November. The highest water temperature value (28.3 °C) was observed in August at the first station and in July at the second one. The reservoir has an alkali character where the measured pH values were higher than 8.0 throughout the year. The maximum pH value was 8.69 (in July) at the first station and 8.67 (in June and July) at the second station. The minimum pH values were measured in November (8.17 at the first station and 8.21 at the second one). The highest dissolved oxygen values were observed in November at both of the stations, which were 9.0 mg/l and 8.5 mg/l, respectively. The minimum dissolved oxygen values were measured in August (7.63 and 7.64 mg/l). The conductivity values had a peak in October at the stations while the lowest values were measured in December. The maximum total Phosphorus values were observed in October in both of the stations (0.113 mg/l) while the minimum values were measured in January (0.007). The highest total Nitrogen value of the first station was 1.20 mg/l in December while that of the second one was 1.49 in July. The lowest values were 0.08 at the first station and 0.17 at the second station and both of them were measured in June. The highest Chl-*a* values of the stations were measured in April which were 15.20 and 12.82, respectively. The lowest Chl-*a* value of the first station was below the measurement range in January. Similarly, the lowest Chl-*a* value of the second station, which was 0.80, was observed in November, December, and February (Table 1).

During the two months when jellyfish was observed, there is a remarkable increase in water temperature values in both stations especially in August 2014. August was the warmest month of the study period with 27.4 °C and 28.7 °C surface water temperature at the first and second stations, respectively. Then, a decline in water temperature was observed and the surface water temperatures were decreased to around 22.0 °C. Oppositely, the dissolved oxygen value of August was the lowest at 7.63 mg/l. There is no obvious alteration in the pH values throughout the year, which was around 8.4. Similar conditions were observed for the other measured physicochemical parameters. The monthly values of the measured physicochemical parameters at the two stations in Ürkmez Reservoir were given in detail (Table 1).

The minimum values of TSI (TP) at the first and second stations were observed in January (32.2) and September (20.0), respectively. The maximum values of TSI (TP) at both stations were observed in October (72.4 at Stat. 1; 79.4 at Stat. 2). Similarly, the minimum scores of TSI (Chl-*a*) were calculated both in December and February (28.4 in both stations) while the maximum values in April (57.3 at Stat. 1; 55.6 at Stat. 2). The minimum TSI (SD) was observed in May at the stations (41.5 at Stat. 1; 40.0 at Stat. 2) and the maximum values in November (77.4 in both stations). The average TSI values show an alteration between 45 and 60 throughout the study period (Figure 2). Similarly, the mean values of August and September were 45 and 52, respectively.

Table 1. Temporal and spatial variation of physicochemical parameters in the Ürkmez Reservoir

Parameters	Stations	March	April	May	June	July	August	September	October	November	December	January	February
Depth (m)	1	15	17	17.5	13	10	13	17	13	23	22	14	16
	2	12	13	12	7	7	8	5	4	18	12	10	10
Secchi Depth (cm)	1	60	160	360	200	230	170	70	110	30	40	80	60
	2	70	120	400	200	240	220	70	110	30	40	60	60
Temperature (°C)	1	16.2	18.9	25.0	26.2	27.8	28.3	22.0	16.7	9.0	10.0	10.8	15.4
	2	16.0	18.5	26.0	26.8	28.3	28.7	22.8	17.0	8.5	9.9	11.0	14.6
pH	1	8.40	8.64	8.60	8.63	8.69	8.45	8.37	8.17	8.30	8.31	8.24	8.38
	2	8.47	8.60	8.65	8.67	8.67	8.38	8.36	8.21	8.24	8.46	8.31	8.39
Dissolved Oxygen (mg/L)	1	9.91	9.35	8.37	7.87	8.06	7.63	8.24	8.65	11.09	10.71	10.43	9.86
	2	10.02	9.05	8.37	8.03	8.05	7.64	8.44	8.80	10.96	10.44	10.31	10.19
Conductivity (µS/cm)	1	332	338	347	356	359	367	371	378	336	306	312	318
	2	331	340	347	355	360	371	371	379	334	310	316	320
Total Phosphorus (mg/L)	1	0.022	0.061	0.033	0.029	0.015	0.014	0.039	0.113	0.05	0.038	0.007	0.025
	2	0.022	0.061	0.033	0.029	0.015	0.014	0.039	0.113	0.05	0.038	0.007	0.025
Total Nitrogen (mg/L)	1	0.23	0.34	0.96	0.08	0.11	0.26	0.33	0.40	0.15	0.64	0.82	1.20
	2	0.40	0.36	0.63	0.17	1.49	0.09	0.75	0.44	0.76	0.76	0.39	0.19
Chl-*a* (µg/L)	1	4.01	15.20	12.02	5.61	1.60	1.60	8.81	5.61	4.01	0.80	*	0.80
	2	9.61	12.82	5.60	2.40	1.60	4.81	4.81	1.60	0.80	0.80	1.60	0.80

***** Below the measurement range.

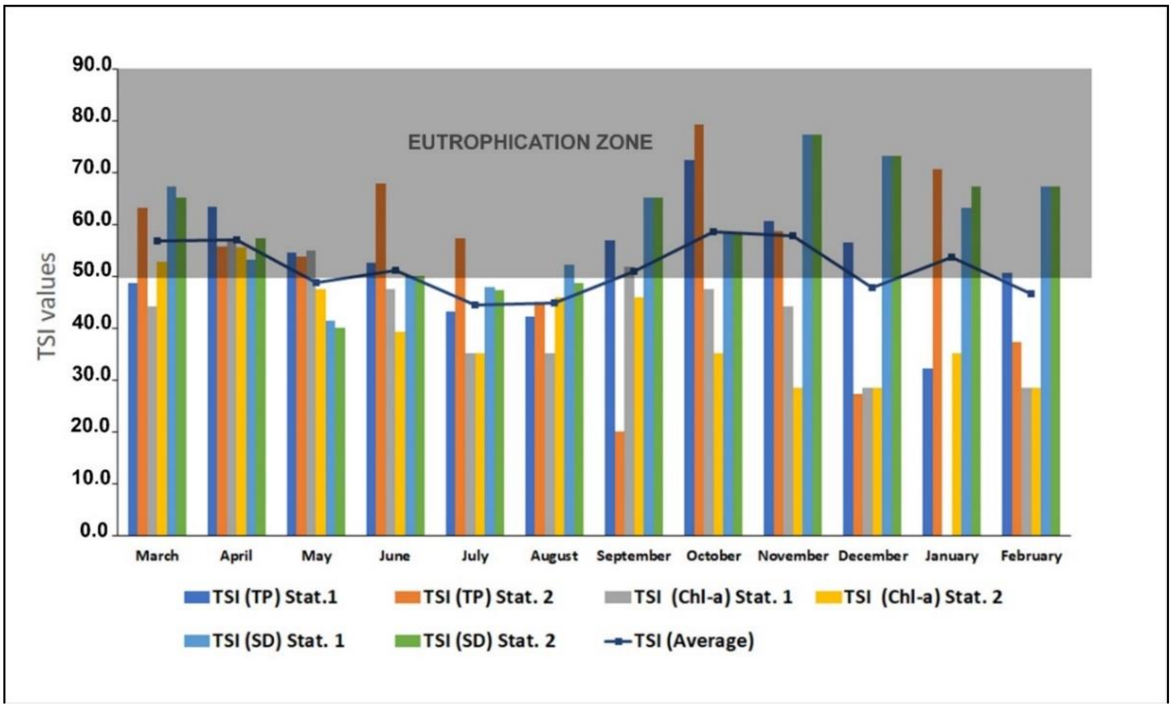

Figure 2. Temporal and spatial variation of calculated TSI values

The most frequent phytoplankton assemblage of the Ürkmez Reservoir was composed of 16 taxa during the sampling period (Figure 3). Most of them belonged to Chlorophyta (4) and Bacillariophyta (4) followed by Miozoa (3) and Euglenozoa (2). Cyanobacteria, Ochrophyta, and Cryptophyta were also represented by only one taxon. Additionally, the data on phytoplankton species (15 taxa) and density in August and September when the medusa was observed, were listed in Table 2.

Table 2. The phytoplankton species associated with the medusa and their relative abundances (%)

Phytoplankton Species	August	September
Aphanizomenon gracile Lemmermann	15	+
Binuclearia lauterbornii (Schmidle) Proschkina-Lavrenko	+	44
Ceratium hirundinella (O.F.Müller) Dujardin	35	5
Dinobryon divergens O.E.Imhof	26	-
Euglena tuberculata Swirenko	+	+
Microcystis aeruginosa (Kützing) Kützing	3	+
Monactinus simplex (Meyen) Corda	2	18
Pantocsekiella ocellata (Pantocsek) K.T.Kiss & E.Ács	+	+
Pediastrum duplex Meyen	+	+
Peridiniopsis cunningtonii Lemmermann	2	+
Peridinium cinctum (O.F.Müller) Ehrenberg	4	12
Pseudopediastrum boryanum (Turpin) E.Hegewald	+	+
Trachelomonas planctonica Svirenko	16	20
Ulnaria acus (Kützing) Aboal	+	+
Ulnaria ulna (Nitzsch) Compère	+	+

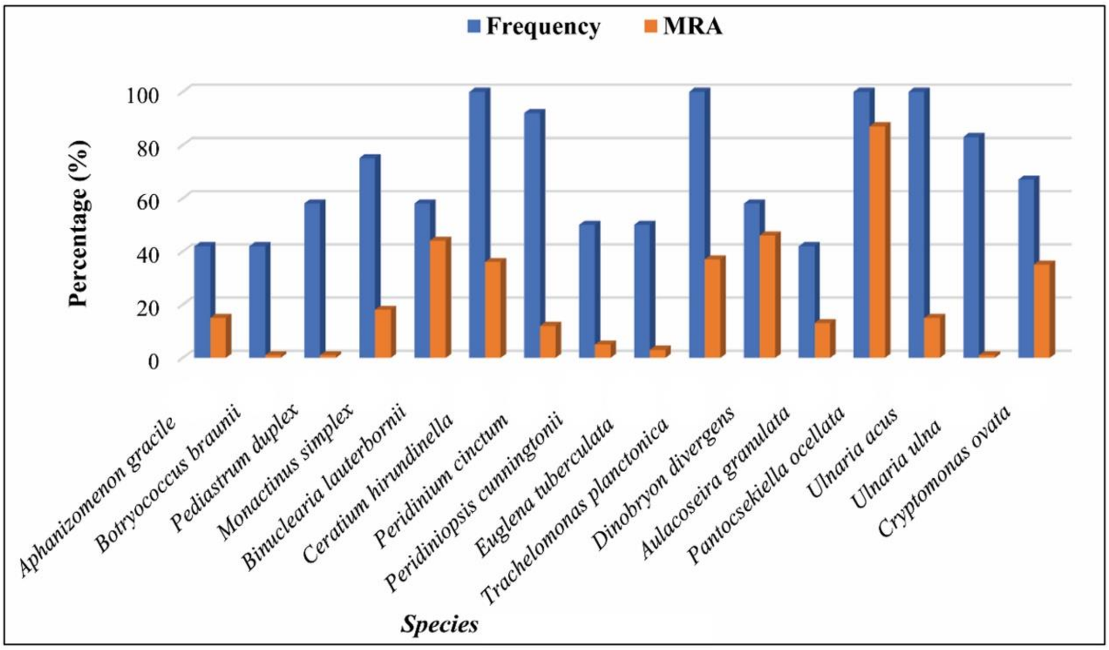

Figure 3. The most frequent (>40%) phytoplankton species and their max. relative abundances (MRA)

DISCUSSION

Based on the calculated TSI values and its morphological characteristics (depth, surface area, water level fluctuation, etc.), Ürkmez Reservoir is categorized as an artificial water body which is meso-eutrophic, shallow, small, and turbulent. In contrast to natural lakes, it is known that pelagic food chain elements (bacteria, phytoplankton, and zooplankton), which are directly affected by water quality, have an important role in the carbon cycle for a long time after initial filling in reservoirs (Saito et al., 2001; Straškrábová et al., 2005). In a microcosm study, strong interactions between *C. sowerbii* and pelagic food web were determined and it was reported that predation effects of the medusa on herbivore zooplankton could lead to significant increases in chlorophyll concentration (Jankowski et al., 2005. Consistent with previous findings, a significant increase in chlorophyll values was observed during the period when medusae were observed in the present study.

Dam lakes or reservoirs, which are generally defined as unbalanced environments, are aquatic ecosystems that are unique in their limnoecological characteristics due to seasonal or periodic filling cases and water level variations caused by human discharge (Geraldes and Boavida, 1999). Dramatic water level fluctuations were also detected in the Ürkmez reservoir (see Table 1). As a result of the prevailing climatic conditions, marked water level changes are widespread phenomenon in reservoirs of the Mediterranean basin (Naselli-Flores and Barone, 2005). Researchers working on phytoplankton dynamics predict that physical instability of the water column is the main factor in changes in species composition (Calijuri et al., 2002). *Monactinus simplex*, *Binuclearia lauterbornii*, *Ceratium hirundinella*, *Peridinium cinctum*, *Trachelomonas planctonica*, *Dinobryon divergens*, *Pantocsekiella ocellate* and *Cryptomonas ovata* were observed as the most frequent phytoplankton species which have high relative abundance values in the pelagic life of the study area. These phytoplankton species were relatively common in several meso-eutrophic reservoir of Turkey (Aysel, 2005). In August and September, *A. gracile*, *B. lauterbornii*, *C. hirundinella*, *D. divergens*, *M. simplex*, and *T. planctonica* were the phytoplankton species associated with *C. sowerbii*. The phytoplankton composition and trophic status are more or less similar to other temperate artificial lakes or reservoirs where the medusa has established summertime populations (Akçaalan et al., 2011; Caputo Galarce et al., 2013; Stefani et al., 2010).

C. sowerbii is one of the most successful invasive freshwater invertebrate species of the world. Having a chitin-covered drought-resistant resting stage can be one of the main reasons for its success and wide distribution worldwide. This species can tolerate extreme environmental conditions and has a suitable life-stage for anthropogenic transport (Jankowski et al., 2008).

There are eight records (+ an aquarium record) of this jellyfish from Turkey and just one of them is a natural lake (Sapanca Lake). The remaining records are mainly reservoirs, ponds, and dam lakes

(Figure 1). Similarly, many of the records from SE Europe and the Middle East are artificial water bodies.

There are several records on the existence of *C. sowerbii* in the Middle East countries (Table 3). The first record of *C. sowerbii* from the area is an artificial lake located in Nile Delta, Egypt in 1956 (Dumont, 1994). The next one is an artificial pond near Baghdad, Iraq (Saadalla, 2006). Later, the species was found in a perennial stream and a small pond near the Sea of Galilee in Israel (Gasith et al., 2011). The last record of the species is an artificial water body near Tehran, Iran (Bagheri et al., 2017).

Table 3. List of *C. sowerbii* records in SE Europe and the Middle East (see distribution map)

Country	Locality	Habitat type	Source
Croatia	Pond Cingi-lingi	Artificial	Stankovic & Ternjej, 2010
Roumania	Pond Ghioroc	Artificial	http://freshwaterjellyfish.org/other-countries-sightings/ 2007
	Pond Near Zona Ghiroda Noua	Artificial	http://freshwaterjellyfish.org/other-countries-sightings/ 2005
	Grebla Pond	Artificial	http://freshwaterjellyfish.org/other-countries-sightings/ 2011
Serbia	Lake Velika Pescara	Artificial	Ludoški et al., 2004
	Sava Lake	Artificial	Kalafatić, 1983; Kalafatić et al. 1999
	Lake Miloševo	Artificial	Database, Faculty of Science, Kragujevac
	Lake Šumarice	Artificial	Database, Faculty of Science, Kragujevac
	Pool near Velika Morova River	Natural	Grozdanić and Manojlović, 1958
	Pond near Trstenik	Artificial	http://freshwaterjellyfish.org/other-countries-sightings/ 2012
	Gazivoda Reservoir	Artificial	Jaksic et al., 2017
Montenegro	Scutari Lake	Natural	Milovanovic & Zivkovic 1965
Bulgaria	Drenovets Reservoir	Artificial	Kozuharov et al., 2017
	Srechenska Bara Reservoir	Artificial	Trichkova et al. (2013)
	Gorni Dabnik Reservoir	Artificial	Regional History Museum – Pleven
	Alexander Stamboliiski Reservoir	Artificial	Stoyneva et al. (2013)
	Iskar Reservoir	Artificial	Kozuharov et al., 2017
	Zhrebchevo Reservoir	Artificial	Traykov; According to Kozuharov et al., 2017
	Kardjali Reservoir	Artificial	Velkov (2004); Traykov et al. (2011)
	Studen kladenetz Reservoir	Artificial	Kozuharov et al., 2017
	Ivaylovgrad Reservoir	Artificial	Bechev (1991)
Turkey	Istanbul	Aquarium	According to Dumont, 1994 (Aquarium record)
	Sapanca Lake	Natural	Akçaalan et al., 2011
	Urkmez Reservoir	**Artificial**	**This study**
	Topçam Reservoir	Artificial	Balık et al., 2001
	Keban Dam Lake	Artificial	According to Dumont, 1994
	Kralkizi Dam Lake	Artificial	Bekleyen et al., 2011
	Pond Ula (Muğla)	Artificial	Gülşahin, 2017
Greece	Canal in Lake Marathon	Artificial	Karaouzas et al., 2015
Cyprus	Reservoir near Klirou	Artificial	http://freshwaterjellyfish.org/other-countries-sightings/
Iran	Chitgar Lake	Artificial	Bagheri et al., 2017
Iraq	Pond	Artificial	Saadalla, 2006
	Pond	Artificial	http://freshwaterjellyfish.org/other-countries-sightings/2002
Israel	Lake Kinneret	Aquarium	Gasith et al., 2011
	Iris Pon	Natural	Gasith e al., 2011
Egypt	Lake Maryut	Artificial	According to Dumont, 2009

This species has more records in Southeastern Europe than in the Middle East (Figure 1, Table 3). There are many reports from Bulgarian and Serbian reservoirs and dam lakes (Jakovčev-Todorović et al., 2010; Kozuharov et al., 2017).

The records of *C. sowerbii* were mainly based on observations of medusae form especially from artificial water bodies such as ponds, reservoirs, and dam lakes in the Middle East and Balkan countries (see Table 3). The two main reasons for this phenomenon can be 1) easiness in observation of jellyfish form in the field study, and 2) overlooking (in general) the polyp form during benthic studies conducted in the mentioned area. Environmental characteristics of artificial water bodies can offer more favorable conditions for medusae form than those of natural lakes but it was reported that natural waters were invaded at a higher rate than artificial waters in New Zealand (Duggan and Eastwood, 2012) and this phenomenon was also observed in the United States (Acker and Muscat, 1976).

New records for the distribution of *Craspedacusta* are given in many parts of the world (Fritz et al., 2007; Fuentes et al., 2019). Researchers try to get information about the origin and exact taxonomic status of the recorded populations with molecular systematic studies. Zhang et al. (2009) suggested that *C. xinyangensis* should be the synonym of *C. sowerbii*, *C. sichuanensis* the synonym of *C. kiatingi* and *C. brevinema* the synonym of *C. sinensis.* The authors also emphasized that the *Craspedacusta* populations distributed outside of China belong to *C. sowerbii* species. Molecular genetic research on the state of *Craspedacusta* populations in Turkey may enable us to obtain valuable results in terms of taxonomic status and origin determination of this unique species.

More studies, which will be focused both on polyp and medusa forms, can indicate the exact distribution pattern of this unique species in the Middle East and Balkan countries. During this period, *C. sowerbii* will continue to expand its distribution area throughout unconscious human activities.

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