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Occurrence of the Alien Freshwater Jellyfish *Craspedacusta sowerbii* Lankester, 1880 (Cnidaria: Hydrozoa) in some Bulgarian Reservoirs

Dimitar Kozuharov[1], Roumen Kalchev[2], Mihaela Beshkova[2], Marieta Stanachkova[1], Lyubomir Kenderov[1], Vasil Vasilev[2] & Teodora Trichkova[2]

[1] Faculty of Biology, Sofia University 'St. Kliment Ohridski', 8 Dragan Tsankov Blvd., 1164 Sofia, Bulgaria; E-mail: mitko_bf@abv.bg
[2] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Blvd., 1000 Sofia, Bulgaria; E-mail: trichkova@zoology.bas.bg

Abstract: The freshwater jellyfish *Craspedacusta sowerbii* is considered of East Asian origin, but currently has already a global distribution. The hydromedusa appearance is sporadic and unpredictable from year to year. *C. sowerbii* may cause serious ecological problems to the pelagic communities of the infested water bodies. It is a predator on zooplankton and may cause a shift in the diet of the zooplankton-feeding fish. The species was recorded first in Bulgaria in 1991, in Ivaylovgrad Reservoir, the Aegean Sea basin. The aim of our work was to study the current distribution of *C. sowerbii* in stagnant water bodies in Bulgaria, using field survey data from the period 2007-2016 and other available sources. The species was found in three of 11 sampled water bodies. Based on our results and published records, nine reservoirs are reported as infested by *C. sowerbii*, four of them belonging to the Aegean Sea basin and five reservoirs within the Danube River basin. The most probable pathway of introduction and spread of *C. sowerbii* in Bulgarian waters were considered human activities mostly related to aquaculture.

Key words: *Craspedacusta sowerbii*, alien species, introduction, distribution, reservoirs, Bulgaria

Introduction

The freshwater jellyfish *Craspedacusta sowerbii* Lankester, 1880 (phylum Cnidaria, class Hydrozoa) is considered of East Asian origin, from the Yangtze River basin in China. Currently, this species is the most widespread freshwater Cnidarian (Dumont 1994). However, the hydromedusa stages appear sporadically and the natural observations are not enough to assess the real local distribution of the species (Duggan & Eastwood 2012). More often the species exists as microscopic podocysts (dormant 'resting bodies'), frustules (larvae produced asexually by budding), planulae (larvae produced sexually by the hydromedusae), or as sessile polyps, which attach to stable surfaces and can form colonies consisting of two to four individuals (Acker & Muscat 1976, Pennak 1989, Angradi 1998, USGS/ NAS 2017). Thus, natural observations are sporadic and unpredictable from year to year. It is not uncommon for *C. sowerbii* to appear in very large quantities in water bodies where it had never been found before. The species usually is found in freshwater lakes and reservoirs, sand pit lakes, quarry ponds, fish ponds, canals, and aquaria (Fritz et al. 2007). It has also been registered in slow-flowing rivers, such as the Ohio River and the Tennessee River in the United States (Beckett & Turanchik 1980, Dumont 1994).

Craspedacusta sowerbii may cause serious ecological problems to the pelagic communities of the infested water bodies. Similar to other Cnidarians, the species is an opportunistic predator. It preys on zooplankton, mainly on big cladocerans, such as

Daphnia spp. and *Ceriodaphnia reticulata* (Jurine, 1820), calanoids, e.g. *Eudiaptomus gracilis* (Sars, 1863), cyclopoids, e.g *Acanthocyclops robustus* Sars, 1863, different rotifers (*Asplanchna* spp., *Polyarthra* spp.), and some insect planktonic larvae, such as *Chaoborus* spp. and chironomids (Dodson & Cooper 1983, Spadinger & Maier 1999). Thus, through direct predation or indirect trophic competition with big zooplanktonic crustaceans, the species may induce cascade effect on primary producers and herbivorous zooplankton or provide a shift in the diet of the zooplankton feeding fish (Smith & Alexander 2008).

The species was first recorded in Bulgaria in 1991 in Ivaylovgrad Reservoir, located on the Arda River, the Aegean Sea basin (Bechev 1991). In the period 2000-2003, it was reported repeatedly for Kardzhali Reservoir on the same river (Velkov 2004, Traykov et al. 2011). Later, in 2009, *C. sowerbii* was found in Srechenska Bara Reservoir, the Danube River basin (Trichkova et al. 2013). Information about the occurrence of *C. sowerbii* in Gorni Dabnik Reservoir, the Vit River catchment, in August 2016 was received from the Regional History Museum in the town of Pleven. The aim of our study was to collect and analyse data on the current distribution of *C. sowerbii* in stagnant water bodies in Bulgaria, using field survey and other available data.

Materials and Methods

The sampling was conducted in five reservoirs and three sand-pit lakes in the Danube River basin and three reservoirs in the Aegean Sea basin in Bulgaria. The samples were taken in summer and autumn. Drenovets Reservoir was sampled twice in 2007 and 2009, Iskar Reservoir in 2011 and 2016, and the rest of the reservoirs and lakes were sampled in 2016.

The studied water bodies are located at altitudes from 126 to 820 m a.s.l. and they are very different in surface area and depth (Table 1). The reservoirs were constructed mainly for power generation and irrigation. Iskar Reservoir is the main water supply for drinking water of Sofia City. Some of the reservoirs were used for industrial purposes, while the sand-pit lakes for gravel and sand extraction. Currently, most of the water bodies are used mainly for aquaculture, recreation and recreational fishing (Table 1).

At sampling sites, some water physical and chemical parameters were measured. The water samples were taken from the surface. The water transparency was measured with a Secchi disk. The water temperature, dissolved oxygen, pH and conductivity were measured in-situ by using portable oxygen, pH and conductivity meters, Schott GmbH and Hanna.

In some cases, the hydromedusae were registered during routine zooplankton sampling. At the deeper sampling points, the zooplankton samples were collected by a quantitative plankton net Judau type of 38 mkm mesh size and 16 cm mouth diameter. At the shallow sampling points, the qualitative and quantitative samples were collected by direct filtering of 50 or 100 dm^3 of water through an Apstein net, with a mesh size of 38 μm and a mouth

Table 1. Characteristics of studied reservoirs and sand-pit lakes and sampling depth

Water body	Altitude	Surface area, ha	Maximum depth, m	Sampling depth, m	Use
Drenovets Reservoir	188	107	28	0-10	Aquaculture, irrigation, recreational fishing
Iskar Reservoir	820	3380	76	0-10 (2011); 0-27 (2016)	Drinking water supply of Sofia City, power generation, recreation and recreational fishing
Ognyanovo Reservoir	631	416	47	0-17	Industrial water supply, irrigation, recreation and recreational fishing
Chepintsi Lake	529	25	19	15	Sand-pit lake, recreational fishing
Negovan Lake (big)	520	64	15	16.5	Sand-pit lake, recreational fishing
Kazichene Lake	550	31	6.5	5.5	Former sand-pit lake, aquapark, recreational fishing
Gorni Dabnik Reservoir	167	1180	19.5	0-18	Irrigation, recreation and recreational fishing
Telish Reservoir	220	230	14.3	0-9	Irrigation, aquaculture and recreational fishing, recreation
Kardzhali Reservoir	332	1640	70	0-40	Power generation, irrigation, aquaculture, recreation and recreational fishing
Studen Kladenets Reservoir	226	2700	40	0-40	Power generation, irrigation, aquaculture, recreation and recreational fishing
Ivaylovgrad Reservoir	126	1500	45	0-45	Power generation, irrigation, aquaculture, recreation and recreational fishing

Table 2. Some water physical and chemical parameters of the studied reservoirs and lakes

No	Water body	Date of sampling	Water temperature (surface), °C	Dissolved oxygen (surface), mg dm^3	pH (surface)	Secchi Disk transparency, m
1	Drenovets Reservoir	14.07.2007	26.5	9.2	–	1.2
		25.09.2009	23.1	8.6	8.50	0.7
2	Iskar Reservoir	10.08.2011	25.0	–	–	–
		11.11.2016	12.8	11.2	8.56	4.4
3	Ognyanovo Reservoir	12.11.2016	13.0	12.0	8.61	2.1
4	Chepintsi Lake	31.07.2016	24.7	9.2	8.20	2.8
5	Negovan Lake (big)	24.07.2016	24.5	8.9	8.12	3.0
6	Kazichene Lake	31.07.2016	25.0	9.2	8.30	1.7
7	Gorni Dabnik Reservoir	19.11.2016	9.7	10.4	8.80	1.7
8	Telish Reservoir	20.11.2016	8.5	9.7	9.00	0.8
9	Kardzhali Reservoir	04.07.2016	26.2	8.8	8.65	5.5
10	Studen Kladenets Reservoir	05.07.2016	29.0	7.6	9.09	8.5
11	Ivaylovgrad Reservoir	07.07.2016	29.2	7.7	8.49	5.5

diameter of 30 cm. The quantitative zooplankton samples were counted by using Dimof's quantitative method, modified by Naidenow (1984). In the reservoirs Gorni Dabnik and Telish, a special pelagic trawl net with a frame of 48x50 cm, length of 3.4 m and 500 µm mesh size was used. It was easily pulled behind the boat, filtering large amounts of water and collecting macro- and mega- plankton organisms. In Iskar Reservoir, the samples were collected by an experimental plankton sampler of Vasilev, with a mesh size of 38 µm and a mouth of 20x20 cm. Direct visual observations from a boat and observations through SCUBA diving were used as well.

Results and Discussion

The water physical and chemical parameters of the studied reservoirs and lakes are given in Table 2. The water temperature ranged from 13°C to 29.2°C. A summer stratification of the water was registered in the deeper reservoirs, such as Kardzhali, Studen Kladenets and Ivaylovgrad. In the other water bodies sampled in autumn, homothermic conditions were established. The values of pH ranged from 8.12 to 9.09 and indicated alkaline conditions in the reservoirs and lakes. The oxygen concentration at the surface ranged from 7.7 mg dm^{-3} in Studen Kladenets to 12.3 mg dm^{-3} in Ognyanovo. The highest value of water transparency was measured in Studen Kladenets Reservoir and the lowest in Negovan and Kazichene lakes (Table 2).

During our study, *C. sowerbii* was found only in three of the eleven studied reservoirs – Drenovets, Iskar, and Studen Kladenets (Table 3). In Drenovets Reservoir, *C. sowerbii* was found during both samplings, with a very high abundance of 800 ind./m^3 in summer of 2007. In Iskar Reservoir, a single specimen was detected in summer of 2011 during SCUBA diving (Table 3). Although intensive studies on zooplankton in this reservoir were conducted in the period 2010-2016, and over 150 zooplankton qualitative and quantitative samples from different sampling points and depths were processed, *C. sowerbii* was not detected (Kozuharov et al. 2016). One possible reason may be that the species did not find favourable conditions for the development of the hydromedusa stage and its appearance in the reservoir was casual.

The finding of *C. sowerbii* in Studen Kladenets Reservoir, which is located on Arda River, was expected (Velkov 2004) (Table 3). The species was already present in Ivaylovgrad Reservoir located downstream on the same river (Bechev 1991), and in Kardzhali Reservoir, upstream on the Arda River (Velkov 2004, Traykov et al. 2011). The infestation of these reservoirs was fist registered in the 1990s – 1991 for Ivaylovgrad and 1998 for Kardzhali reservoirs. It was then repeatedly reported for Kardzhali Reservoir in 2000-2003 (Table 3), which showed an established and stable population. However, we did not record the species during our sampling in 2016 in Kardzhali and Ivaylovgrad reservoirs despite of the favourable temperatures (Table 2). It is possible, that the heavy phytoplankton blooms by *Ceratium hirundinella* (O. F. Müller) Dujardin, 1841, observed in Kardzhali Reservoir in July 2016, suppressed the development of *C. sowerbii* and the other zooplankton species in this period.

The occurrence of *C. sowerbii* in Gorni Dabnik Reservoir was observed in August 2016 by experts from the Regional History Museum in the town of Pleven (Table 3). During our visit and sampling in this reservoir and the neighbouring Telish Reservoir, later in the same year, the species was not found most probably because of the low water temperature.

A single specimen of *C. sowerbii* was observed by I. Traykov (unpublished data) in Zhrebchevo Reservoir in July 2013.

In Bulgaria, *C. sowerbii* was reported in the 1990s, first from Ivaylovgrad Reservoir in 1991 (Bechev 1991), and then from Kardzhali Reservoir in 1998 (Velkov 2004). Most likely, the species occurred earlier in the country. There are some unpublished data of Prof. Naidenow, that the hydromedouse were found in the middle of the 1980s in South Bulgarian reservoirs, but more detailed information about these findings is lacking. In some neighbouring countries, the species was reported much earlier, e.g. in 1958 from Serbia (Jakovčev-Todorović et al. 2010). The first records of the species in Central European countries were from the 1970s (Dumont 1994).

The main factors, which may limit the distribution of *C. sowerbii* are water temperature and altitude of lakes. The species colonises preferably warmer basins with temperatures over 20-25°C in summer (Pennak 1989, Angradi 1998, USGS/ NAS 2017). Lake bottoms in the littoral zone, overgrown with vegetation, such as *Myriophyllum* spp. and *Potamogeton* spp., are also suitable for *C. sowerbii*, especially for development of the polyps. The altitude of the infested reservoirs in Bulgaria ranges from 126 m (Ivaylovgrad) to 445 m (Srechenska Bara), Iskar Reservoir being the only exception of higher altitude, 820 m. All the records were made in summer or early autumn, in the period from the beginning of July to the beginning of October. During our survey, the hydromedusae were found at water temperatures from 23.1 to 29.0°C (Tables 2 and 3). Velkov (2004) reported an average water temperature of 20°C in Kardzhali Reservoir in the period of appearance of the hydromedusae. Similar temperature conditions were reported for reservoirs in Serbia (Jakovčev-Todorović et al. 2010) and Kosovo (Jaksic et al. 2017).

According to the records so far, *C. sowerbii* have infested water bodies in different regions of Bulgaria – three reservoirs in the Arda River catchment and one reservoir in the Tundzha River catchment, belonging to the Aegean Sea basin, and five reservoirs within the Danube River basin (Table 3). The reservoirs in the Danube River basin are also affiliated to different river catchments. This shows individual introductions of the species to the reservoirs most likely with human aid. As the reservoirs are currently used for aquaculture (some very intensively, e.g. Drenovets) and/or recreational fishing, we assume that the most probable pathway of introduction and spread of *C. sowerbii* was the transfer of aquatic vegetation from one water body to another and different aquaculture activities. Unaided

Table 3. Distribution of *Craspedacusta sowerbii* in the Bulgarian reservoirs based on field survey and published data

No	Water body	River basin	Latitude	Longitude	Date of record	Data source
1	Drenovets Reservoir	Medovnitsa River, Danube River basin	43.69611	22.91528	14.07.2007, 25.09.2009	Present study
2	Srechenska Bara Reservoir	Barzia, River, Danube River basin	43.21139	23.19917	02.10.2009	Trichkova et al. (2013)
3	Iskar Reservoir	Iskar River, Danube River basin	42.47564	23.55835	10.08.2011	Present study
4	Gorni Dabnik Reservoir	Vit River, Danube River basin	43.37024	24.33326	08.2016	Regional History Museum – Pleven
5	Alexander Stamboliiski Reservoir	Yantra River, Danube River basin	43.10813	25.11663	19.08.2011, 16.07.2012	Stoyneva et al. (2013)
6	Zhrebchevo Reservoir	Tundzha River, Aegean Sea basin	42.59278	25.95056	27.07.2013	I. Traykov (unpublished data)
7	Kardzhali Reservoir	Arda River, Aegean Sea basin	41.6267	25.3307	1998, 2000-2002, 30.09-04.10.2003	Velkov (2004), Traykov et al. (2011)
8	Studen Kladenets Reservoir	Arda River, Aegean Sea basin	41.62088	25.63753	08.07.2016	Present study
9	Ivaylovgrad Reservoir	Arda River, Aegean Sea basin	41.58774	26.10776	25.09.1992	Bechev (1991)

spread was only possible in the three reservoirs, belonging to the Arda River catchment.

Most of the reservoirs infested by *C. sowerbii* have large surface areas (from 1144 to 3380 ha), and only two reservoirs are comparatively smaller: Drenovets (107 ha) and Srechenska Bara (75 ha). The reservoirs are used for multiple purposes (Table 2). This fact probably facilitated the introduction of the species to these reservoirs, because it is usually assumed that larger water bodies are colonised more easily by aquatic invasive alien species, presumably due to a greater number of access points and a larger number of human users (Trichkova et al. 2007).

Higher abundances of the hydromedusae were detected in the smaller reservoirs Drenovets (present study) and Srechenska Bara (Trichkova et al. 2013), but also in some of the bigger reservoirs: Kardzhali and Alexander Stamboliiski (Traykov et al. 2011, Stoyneva et al. 2013). Therefore, *C. sowerbii* may pose a serious threat to the pelagic communities of the infested reservoirs in Bulgaria, and cause an adverse impact on the trophic relations between the zooplankton and phytoplankton, provide a shift in the diet of the zooplankton feeding fish, as well as influence negatively the self-purification processes in the reservoirs (Dodson & Cooper 1983, Spadinger & Maier 1999, Jankowski & Ratte 2000, Smith & Alexander 2008, Didziulis & Zurek 2013).

Conclusions

The obtained results from the conducted field surveys and review of available sources showed that the alien freshwater jellyfish *C. sowerbii* has already spread in several regions in Bulgaria, in different river catchments affiliated to two water basins: the Aegean Sea basin (four infested reservoirs) and the Danube River basin (five infested reservoirs). In some of the reservoirs (Kardzhali), the population of *C. sowerbii* has been stable throughout the years and the hydromedusa stage was observed regularly in summer. In other reservoirs (Iskar, Zhrebchevo) single specimens were observed sporadically. Probable pathway of introduction and spread of *C. sowerbii* was the unintentional introduction through transfer of aquatic vegetation and aquaculture activities.

It may be expected that *C. sowerbii* influence negatively the zooplankton communities in the infested reservoirs. However, no studies on its impact have been carried out so far. Therefore, further studies, including regular monitoring and risk assessment of *C. sowerbii* need to be initiated. Additionally, preventive and control measures on the presence of the species in aquaculture material, equipment and facilities should be provided.

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References

Acker T. S. & Muscat A. M. 1976. The ecology of *Craspedacusta sowerbyi* Lankester, a freshwater hydrozoan. American Midland Naturalist 95: 323-336.

Angradi T. R. 1998. Observations of freshwater jellyfish, *Craspedacusta sowerbyi* Lankester (Trachylina: Petasidae), in a West Virginia Reservoir. Brimleyana: The Journal of the North Carolina State Museum of Natural Sciences 25: 35-42.

Bechev D. 1991. *Craspedacusta* in Bulgaria (Hydrozoa: Olindiidae). Travaux Scientifiques de l'Université de Plovdiv – Biologie 29 (6): 33-34. (in Bulgarian, English summary)

Beckett D. C. & Turanchik E. J. 1980. Occurrence of the freshwater jellyfish *Craspedacusta sowerbyi* Lankester in the Ohio River. Ohio Journal of Science 32: 323-324.

Didziulis V. & Zurek R. 2013. NOBANIS Invasive Alien Species Fact Sheet – *Craspedacusta sowerbii*. From: Online Database of the European Network on Invasive Alien Species (NOBANIS) www.nobanis.org; Date of access 03/18/2017.

Dodson S. & Cooper S. 1983 Trophic relationships of the freshwater jellyfish *Craspedacusta sowerbyi* Lankester, 1880. Limnology and Oceanography 28 (2): 345-351.

Duggan I. & Eastwood K. 2012. Detection and distribution of *Craspedacusta sowerbii*: Observations of medusa are not enough. Aquatic Invasions 7 (2): 271-275.

Dumont H. J. 1994. The distribution and ecology of the fresh- and brakish- water medusae of the world. Hydrobiologia 272: 1-12.

Fritz G., Schill R., Pfannkuchen M. & Brümmer F. 2007. The freshwater jellyfish *Craspedacusta sowerbii* Lankester, 1880 (Limnomedusa: Olindiidae) in Germany, with a brief note on its nomenclature. Journal of Lmnology 66 (1): 54-59.

Jakovčev-Todorović D., Đikanović V., Skorić S. & Cakić P. 2010. Freshwater jellyfish *Craspedacusta sowerbyi* Lankester, 1880 (Hydrozoa, Onindiidae) – 50 years' observation in Serbia. Archive of Biological Sciences, Belgrade 62: 123-127.

Jaksic T., Vasic P., Valjarevic A., Djukic N., Vukanic V. & Rakonjac V. 2017 The first record of the freshwater jellyfish *Craspedacusta sowerbii* Lankester, 1880 (Hydrozoa) in in Kosovo. Acta Zoologica Bulgarica, Supplement 9: 283-285.

Jankowski T. & Ratte H. 2000. On the influence of the freshwater jellyfish *Craspedacustra sowerbii* on the zooplankton communities. Verhandlungen des Internationalen Verein Limnologie 27: 1-4.

Kozuharov D., Raikova G., Stefanova M. & Fikovska E. 2016. Dynamics of the zooplankton composition of the system Iskar River – Iskar Reservoir in relation to some environmental factors. Comptes rendus de l'Academie bulgare des Sciences 69 (8): 1027-1036.

Naidenow W. 1984 Composition and ecology of the zooplankton from the Danube River and Bulgarian continental basins. Summary of Doctor of Sciences Thesis, Institute of Zoology, Bulgarian Academy of Sciences, Sofia, 43 p.

Pennak R. W. 1989. Coelentera. In: Fresh-Water Invertebrates of the United States: Protozoa to Mollusca, 3rd edition. New York: John Wiley & Sons, pp. 110-127.

Smith A. & Alexander J. 2008. Potential effects of the freshwater jellyfish *Craspedacusta sowerbii* on zooplankton community abundance. Journal of Plankton Research 30 (12): 1323-1327.

Spadinger R. & Maier G. 1999. Prey selection and feeding of the freshwater jellyfish, *Craspedacusta sowerbii*. Freshwater Biology 41: 567-573.

Stoyneva M., Trajkov I., Tosheva A., Uzunov B., Zidarova R. & Descy J.-P. 2013. Monitoring of the phytoplankton in standing water bodies as an element of the National Programme for the Monitoring of Surface Waters in 2011-2013. Project Contract No 2081/ 01.09.2011, Report for the Ministry of Environment and Water of Bulgaria, Ecotan Company.

Traykov I., Boyanovsky B. & Zivkov M. 2011. Composition and abundance of zooplankton in Kardzhaly Reservoir. Bulgarian Journal of Agricultural Science 17 (4): 501-511.

Trichkova T. A., Kotsev A. A., Popov A., Zivkov M. T., Kozuharov D. S., Botev I. S., Hubenov Z. K., Dimitrov S. & Cheshmedjiev S. D. 2007. Assessment of zebra mussel (*Dreissena polymorpha*) infestation risk using GIS for water basins in the North-West Bulgaria. US Army Corps of Engineers – Defense Technical Information Center, 54 p.

Trichkova T. Tyufekchieva V., Kenderov L., Vidinova Y., Botev I., Kozuharov D., Hubenov Z., Uzunov Y., Stoichev S. & Cheshmedjiev S. 2013. Benthic macroinvertebrate diversity in relation to environmental parameters, and ecological potential of reservoirs, Danube River Basin, North-West Bulgaria. Acta Zoologica Bulgarica 65 (3): 337-348.

Velkov B. 2004. *Craspedacusta sowerbii* (Hydrozoa: Olindiidae) in the Kardzhali Reservoir. Acta Zoologica Bulgarica 56 (2): 239-240.

USGS/ NAS 2017. Fact sheet on *Craspedacusta sowerbyi* Lankester, 1880. USGS – United States Geological Survey, NAS – Nonindigenous Aquatic Species, Wetland and Aquatic Research Center, https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=1068