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BLOOM-FORMING AND ABUNDANT DINOFLAGELLATES IN THIRTEEN RESERVOIRS IN BULGARIA (2018-2020)

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Abstract. The present paper reports on 34 cases of blooms (21) and abundance (13) of 8 taxa from 6 genera of the class Dinophyceae in thirteen reservoirs in Bulgaria during the summer-early autumn periods of 2018-2020. During the blooms, biomass of dinoflagellates reached the maximum value of 93.3% in the Lenovo reservoir (*Ceratium hirundinella* in September 2019), while the lowest contribution was 25.2% in the reservoir Svezhen (*Gymnodinium* cf. *uberrimum* in August 2020). The contribution of abundant dinoflagellates ranged between 5% in the reservoir Aheloy (*Ceratium furcoides* in August 2020) and 18.5% in the reservoir Trakiets (*Ceratium hirundinella* in July 2020). Two of the quantitatively important species, *Peridinium bipes* and *Apocalathium* cf. *aciculıferum*, found as dominant in the reservoirs Aheloy, Radnevo and Tyurkmen, are known as potential toxin producers.

Key words: biomass, Dinophyceae, dominants, phytoplankton, toxic species

INTRODUCTION

Dinoflagellates are a group of single-celled protists with golden brown pigmentation, which swim through flagella. They are divided into two groups,

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those having a peculiar cellulose wall-cover under their plasmalemma (*amphiesma*, formerly named *theca*) and those without such a wall-cover (Grigorsky et al. 1998, Temniskova & Stoyneva 2011, Stoyneva & Uzunov 2017). Dinoflagellates are a large group of primary producers, most of which are representatives of the marine phytoplankton, but are also present in freshwater habitats (Kim et al. 2020, Guiry & Guiry 2021). They play an essential environmental role as a food source for higher levels in food chains (Breteler et al. 1999). In dominance, they cause harmful blooms in the seas and degrade water quality in freshwater systems (Rengefors & Legrand 2001, Anderson et al. 2002, Hirabayashi et al. 2007). Some species of dinoflagellates are well known as potential toxin producers (Rengefors & Legrand 2001). In the freshwater algal communities, dinoflagellates are commonly dominating according to biomass in late summer, but also in late winter and early spring, the latter fact been poorly studied (Sommer et al. 1986, Rengefors & Legrand 2001, Temniskova & Stoyneva 2011). This algal group was scarcely studied in Bulgarian reservoirs (Michev & Stoyneva 2007). The present paper reports on the mass abundance and blooms of some members of the class Dinophyceae in thirteen reservoirs in the country in the last years (2018-2020).

MATERIAL AND METHODS

The study was conducted in thirteen reservoirs during the period 2018 to 2020: Zhrebchevo (IBW2545), Kurdzhali (IBW1668), Pyasuchnik (IBW1472), Lenovo (IBW1592), Dushantsi (IBW1408), Tsankov Kamuk (IBW9829), Tyurkmen (IBW1612), Troyan (IBW2247), General Nikolaevo 1 (IBW1558), Svezhen (IBW1995), Aheloy (IBW3032), Radnevo (IBW2261) and Trakiets (IBW1677) (with IBW identification numbers provided after Michev & Stoyneva 2007) - **Fig. 1**, **Table 1**. These water bodies are used as important water resources in irrigation, aquaculture and for recreational purposes (Michev & Stoyneva 2007).

Twenty-four water samples for phytoplankton analysis were collected by Niskin-Type water sampler 5 L model (Hydro-Bios Apparatebau GmbH, Germany). The depth of the euphotic layer was determined by measuring the water transparency with a 20 cm diameter Secchi disk. The phytoplankton samples were collected and processed by standard methods of fixation with formalin to final concentration 4% and further sedimentation (ISO5667-1:2006/AC: 2007; ISO5667-3: 2003/AC: 2007). Microscope work has been done on Bürker chamber. The species composition was determined by light microscope (Carl Zeiss, Axioscope 2 plus) with magnification 400x using standard taxonomic literature with critical use of AlgaeBase (Guiry & Guiry 2021). The main counting unit was the cell and the biomass was estimated by the method of stereometrical approximations (Rott 1981, Deisinger 1984). The total biomass of each sample was assessed as the amount of biomass of all species, summarized by taxonomic groups. Abundant

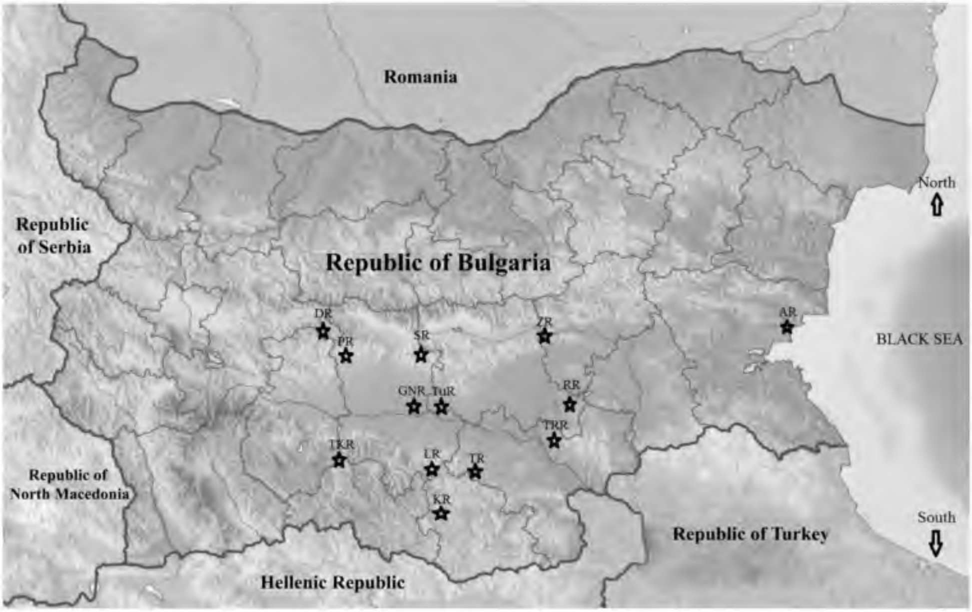

Fig. 1. Map of the Republic of Bulgaria with the location of sampling sites indicated. **Legend:** AR - Aheloy Reservoir, DR - Dushantsi Reservoir, GNR - General Nikolaevo 1 Reservoir, KR - Kurdzhali Reservoir, LR - Lenovo Reservoir, PR - Pyasuchnik Reservoir, RR - Radnevo Reservoir, SR - Svezhen Reservoir, TKR - Tsankov Kamuk Reservoir, TR - Trakiets Reservoir, TRR - Trayan Reservoir, TuR - Tyurkmen Reservoir, ZR - Zhrebchevo Reservoir.

species were determined standardly according to the percentage contribution of individual species to the total biomass (Stoyneva 2000).

RESULTS

During the study period, 34 cases of mass developments (13) and blooms (21) of six species and representatives of two genera of class Dinophyceae were registered in all thirteen studied reservoirs. The results are organized in a table form, indicating the contribution of each species to the total phytoplankton biomass (TPB) and its real biomass values (**Table 1**). Since this table is organized according to the alphabetical order of algal taxa, here we note the cases of detected common development or alteration of quantitatively important dinoflagellate species by reservoirs: 1) In the reservoir Svezhen, in August 2020 *Gymnodinium* cf. *uberrimum* dominated and *Ceratium furcoides* was abundant; 2) In 2020, in the reservoir General Nikolaevo, the dominance of *Peridinium* sp. in July was followed by mass abundance of *Peridiniopsis* sp. in August; 3) In 2019, in the reservoir Radnevo the August dominance of *Apocalathium* cf. *aciculiferum*, in September was followed by the mass development of *Ceratium furcoides*; 4) In 2020, in the reservoir Aheloy *Peridinium* sp. was abundant during the dominance of *Peridinium bipes* in July and August, and then started to dominate in October (**Table 1**).

Table 1. The biomass values and contribution of each quantitatively important dinoflagellate species to the total phytoplankton biomass (TPB) in the thirteen Bulgarian reservoirs (2018-2020).

Algal species	Locality (Reservoir)	Sampling period	Biomass value (mg L^{-1})	% of TPB
Apocalathium cf. *aciculiferum*	Radnevo	August 2019	12.7	36.6
Ceratium furcoides	Aheloy Dam	August 2020	1.008	5
Ceratium furcoides	Lenovo	September 2019	21.105	93.3
Ceratium furcoides	Radnevo	September 2019	1.114	11.1
Ceratium furcoides	Svezhen	August 2020	1.730	12.8
Ceratium hirundinella	Kurdzhali	October 2018	7.37	60
Ceratium hirundinella	Pyasuchnik	September 2018	7.96	83.5
Ceratium hirundinella	Trakiets	July 2020	2.074	18.5
Ceratium hirundinella	Tsankov Kamuk	September 2019	5.036	36.7
Ceratium hirundinella	Zhrebchevo	October 2019	4.64	56.9
Ceratium hirundinella	Zhrebchevo	September 2020	1.104	25
Ceratium hirundinella	Zhrebchevo	September 2020	4.853	32.6
Gymnodinium cf. *uberrimum*	Svezhen	August 2020	3.429	25.2
Peridiniopsis sp.	General Nikolaevo 1	August 2020	2.319	14
Peridiniopsis sp.	Aheloy Middle	August 2020	6.801	3.14
Peridiniopsis sp.	Aheloy Middle	October 2020	15.183	34.74
Peridiniopsis sp.	Aheloy Tail	October 2020	25.527	41.26
Peridiniopsis sp.	Aheloy Dam	October 2020	13.44	27.13
Peridinium bipes	Aheloy Middle	August 2020	9.240	35.9
Peridinium bipes	Aheloy Middle	July 2020	5.181	54.3
Peridinium bipes	Aheloy Tail	July 2020	9.804	72.89
Peridinium bipes	Aheloy Dam	July 2020	7.155	63.4
Peridinium bipes	Aheloy Tail	August 2020	9.056	34.54
Peridinium bipes	Aheloy Dam	August 2020	2.615	13
Peridinium cf. *bipes*	Turkmen	July 2019	12.496	71.7
Peridinium sp.	Aheloy Middle	July 2020	1.408	14.8
Peridinium sp.	Aheloy Middle	August 2020	3.426	13.3
Peridinium sp.	Aheloy Tail	July 2020	1.609	11.96
Peridinium sp.	Aheloy Dam	July 2020	1.288	14.7
Peridinium sp.	Aheloy Dam	August 2020	1.26	5.6
Peridinium sp.	General Nikolaevo 1	July 2020	4.792	28.9
Peridinium sp.	Troyan	August 2019	16.008	68.7
Unruhdinium cf. *kevei*	Aheloy Tail	October 2020	8.147	13.17
Unruhdinium cf. *kevei*	Dushantsi	September 2019	32.496	81.73

DISCUSSION

During the study, eight taxa from six genera were found as dominants or as abundant algae in the studied water bodies (**Table 1**). Their ecological peculiarities and former data on the distribution in Bulgarian reservoirs are discussed below.

Representatives of the genus *Ceratium* usually inhabit stratified water bodies with low levels of nutrients (Grigorsky et al. 2003). During the study, we identified 2 species from this genus: *C. hirundinella* (O. F. Müller) Dujardin and *C. furcoides* (Levander) Langhans. According to Reynolds et al. (2002), *C. hirundinella* is an eury-trophic species that often develop with cyanoprokaryotes, especially with *Microcystis aeruginosa* (Kützing) Kützing. *Ceratium hirundinella* and *Peridinium* sp. have been reported among the dominants in Bistritsa, Tsankov Kamuk reservoirs and in fish ponds (Dochin & Ivanova 2015, Dochin & Ivanova 2017a, Dochin & Ivanova 2017c, Dochin et al. 2020). *C. hirundinella* was among the most abundant in the reservoirs Koprinka, Kavaka and Konush (Dochin et al. 2017, Dochin & Ivanova 2017b, Dochin & Ivanova 2017c). In late summer and early autumn, *Ceratium hirundinella* was among the most common species in the reservoirs Iskur, Pchelina, Yasna Polyana, Borovitsa, Dospat, Batak, Zhrebchevo and Stouden Kladenets (Kalchev et al. 2005, Beshkova & Saiz 2006, Teneva et al. 2010, Dochin & Stoyneva 2016, Dochin et al. 2018, Dochin 2019).

Ceratium furcoides dominates water bodies with high biogens concentration, and its excessive development can harm fish populations by depleting oxygen (Matsumura-Tundisi et al. 2010, Silva et al. 2012, Cavalcante et al. 2016). According to Belkinova et al. (2014) *C. furcoides* was among the most abundant species in the Ovcharitsa reservoir and was registered among the dominants in the reservoirs Kurdzhali and Koprinka (Gecheva et al. 2020). *C. furcoides* was reported among the most abundant species in different water bodies, namely Skalenski Lakes, waterbodies in Bulgarka Nature Park and fish ponds near Plovdiv (Teneva et al. 2014, Stoyanov et al. 2016a, Dochin 2020). According to Stephaniak et al. (2007) due to the ability of the *C. furcoides* for vertical migration, it successfully competes with cyanoprokaryotes. This is in agreement with our data from this study, that in Aheloy reservoir representatives of the Dinophyceae class, including *C. furcoides*, caused blooms in coexistence with cyanoprokaryotes.

According to Niesel et al. (2007), *Gymnodinium uberrimum* (G. J. Allman) Kofoid & Swezy occurs in oligo to mesotrophic deep stratified reservoirs at low phosphorus concentrations. Klymiuk & Barinova (2015) reported that *G. uberrimum* inhabits slightly alkaline and moderately polluted with nutrient water. The same species is identified in oxbow-lakes in Kőrös area in Hungary (Grigorsky et al. 1998). *Gymnodinium* cf. *uberrimum* was published among the dominants in the mountain reservoir Dospat reservoir during the period 2010-2012 (Dochin & Stoyneva 2014, Dochin & Stoyneva 2016) and in other mountain reservoirs Belmeken and Beli Iskur, *Gymnodinium* sp. was registered among the most abundant algae (Belkinova et al. 2014). *Gymnodinium uberrimum* was identified in the high-altitude Batak reservoir (Dochin et al. 2018).

In the freshwater blooms the most common genera from class Dinophyceae are *Ceratium*, *Peridinium* and *Peridiniopsis* (Niesel et al. 2007). The currently separated from the genus *Peridiniopsis* species *Unruhdinium kevei* (Grigorszky & F. Vasas) Gottschling (Syn. *Peridiniopsis kevei* Grigorszky & F. Vasas) occurs in both oligotrophic and eutrophic water bodies, being widespread in terms of nutrients but develops in narrow temperature and alkaline ranges (Grigorsky et al. 2001). According to Owsianny & Grabowska (2009) *U. kevei* has been classified as an invasive species in reservoirs in Poland and has been found in some reservoirs in Russia (Korneva et al. 2015).

Many species of the genus *Peridinium* are found as codominant species, but often they are in polydominant, and rarer are in monodominant assemblages (Grigorsky et al. 1998). Some species, such as *Peridinium willei* Huitfeldt-Kaas, *Peridinium bipes* F. Stein, *Peridinium gatunense* Nygaard, *Unruhdinium minimum* (Qi Zhang, G. X. Liu & Z. Y. Hu) Gottschling (Syn. *Peridinium minimum* Qi Zhang, G. X. Liu & Z. Y. Hu) and *Apocalathium aciculiferum* (Lemmermann) Craveiro, Daugbjerg, Moestrup & Calado (Syn. *Peridinium aciculiferum* Lemmermann), have been reported as toxic dinoflagellates, common in freshwater water bodies (Rengefors & Legrand 2001, Hirabayashi et al. 2007, Yatigammana et al. 2011, Niesel et al. 2007). According to Rengefors & Legrand (2001) *A. aciculiferum* produces an allelopathic substance that inhibits the development of competing phytoplankton species. This species was reported from lakes in Bulgaria, namely Skalenski Lakes (Teneva et al. 2014) and was reported by Grigorsky et al. (1998) in oxbow-lakes in Hungary.

Some dinoflagellates produce toxins as an adaptive defense strategy to reduce the growth of crustaceans and fish (Rengefors & Legrand 2001). *Peridinium bipes* have an algaecidic effect on cyanoprokaryotic *Microcystis aeruginosa* (Wu et al. 1998, Manage et al. 2000, Nakamura et al. 2003). According to Hirabayashi et al. (2007) *P. bipes* responds to changes in the environment such as electrical conductivity, pH and transparency. *Peridinium bipes*, found as bloom-forming species in this study (**Table 1**), was known as a harmful species in Bulgaria. In the Koprinka reservoir in the periods 1959-1961 and 1988-1989, each year mass fish mortality occurred in the summer as a result of its massive blooms (Michev & Stoyneva 2007).

CONCLUSION

In conclusion, it is possible to state that some of the dinoflagellates recorded in this study as abundant or dominant species, could be harmful and cause water quality problems. Therefore, the fact of increasing finding of their frequent blooms in the reservoirs of Bulgaria, should serve as a signal to draw more attention of researchers to this group of algae.

CONFLICT OF INTERESTS

The author declares that there is no conflict of interest regarding the publication of this article.

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