

STUDIA BOTANICA HUNGARICA

Volume 47(2)

2016

Iris Hungarica

Museum
Historico-Naturale
Hungaricum



DISTRIBUTION OF INVASIVE SPECIES *ACTINOCYCLUS NORMANII* (HEMIDISCACEAE, BACILLARIOPHYTA) IN SERBIA

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Vidaković, D., Krizmanić, J., Subakov-Simić, G. & Karadžić, V. (2016): Distribution of invasive species *Actinocyclus normanii* (Hemidiscaceae, Bacillariophyta) in Serbia. – *Studia bot. hung.* 47(2): 201–212.

Abstract: In Serbia *Actinocyclus normanii* was registered in several rivers and canals. In 1997, it was found as planktonic species in the Tisza River and in benthic samples (in mud) in the Veliki Bački Canal. In 2002, it was found as planktonic species in the Danube–Tisza–Danube Canal (Kajtasovo) and the Ponjavica River (Brestovac and Omoljica). Four years later, in 2006, the species was found in plankton, benthos and epiphytic samples in the Ponjavica River (Omoljica). *A. normanii* is a cosmopolite, alkalibiontic and halophytic species. It occurs in waters with moderate to high conductivity and it is indicator of eutrophied, polluted waters. Its spread could be explained by eutrophication of surface waters.

Key words: *Actinocyclus normanii*, distribution, invasive species, Serbia

INTRODUCTION

An invasive species is a non-native species to a new area, whose introduction has a tendency to spread and cause extinction of native species and is believed to cause economic or environmental harm or harm to human, animal, or plant health. Invasive species may impact native flora and fauna causing severe disturbance in food webs. Invasions by marine macroscopic algae (WILLIAMS and SMITH 2007) and vascular plants (HEJDA *et al.* 2009) are well known. However, invasions by freshwater taxa are poorly understood (KORNEVA 2007, KAŠTOVSKÝ *et al.* 2010).

According to literature data some of known freshwater invasive algae are: *Cylindrospermopsis raciborskii* (e.g. SZALAI 1942, PADISÁK 1997, BRIAND *et al.* 2004, KAŠTOVSKÝ *et al.* 2010), *Didymosphenia geminata* (e.g. SUBAKOV-SIMIĆ and CVIJAN 2004, BLANCO and ECTOR 2009, GILLIS and CHALIFOUR 2010, KILROY and UNWIN 2011), *Thalassiosira baltica* (EDLUND *et al.* 2000),

Actinocyclus normanii (e.g. KORNEVA 2014), *Cyclotella comensis* (MIKHEYEVA and GENKAL 2006, GARRISON 2013). A detailed list of freshwater invasive taxa is shown in the paper of KAŠTOVSKÝ *et al.* (2010). Published data about the distribution of invasive algae species in Serbia are scarce: *Actinocyclus normanii* (ČAĐO *et al.* 2005, 2006), *Didymosphenia geminata* (SUBAKOV-SIMIĆ and CVIJAN 2004, SUBAKOV-SIMIĆ *et al.* 2006, KRIZMANIĆ *et al.* 2015, MARINKOVIĆ *et al.* 2016) and *Cylindrospermopsis raciborskii* (ĆIRIĆ *et al.* 2010, CVIJAN and FUŽINATO 2011, 2012, KARADŽIĆ *et al.* 2013, JOVANOVIĆ *et al.* 2015, PREDOJEVIĆ *et al.* 2015, DROBAC *et al.* 2016).

According to some authors, two forms of *A. normanii* are distinguished: *f. normanii* and *f. subsalsus* (e.g. KRAMMER and LANGE-BERTALOT 2004, KAŠTOVSKÝ *et al.* 2010, MEDVEDEVA and NIKULINA 2014, GUIRY and GUIRY 2016). The distinction of these forms is based on differences of valve diameter and water type preferences (sea or fresh water) (HUSTEDT 1957). Contrary, according to KISS *et al.* (1990), *f. subsalsus* has no taxonomical value and they propose to use only the name *A. normanii*. According to them, as well as other authors (e.g. BELCHER and SWALE 1979), the supposed difference in cell size of sea populations and fresh water populations is not sufficient for separation and does not merit taxonomic value.

Actinocyclus normanii (W. Gregory ex Greville) Hustedt was considered to be a marine and brackish species (KIPP *et al.* 2012). During the last decades it has been recorded all over the world in eutrophic rivers and lakes (KISS *et al.* 2012). Its occurrence rate increase and it might be considered as an invasive species (KORNEVA 2007, KISS *et al.* 2012).

Actinocyclus normanii f. subsalsus (Juhlin-Dannfelt) Hustedt could originally be a native marine or brackish water species (Baltic Sea, Caspian Sea) (LIUKKONEN *et al.* 1997). It is known to spread from brackish into common freshwaters, throughout the world, and was considered as invasive or potentially invasive species (KAŠTOVSKÝ *et al.* 2010, KIPP *et al.* 2012). According to KIPP *et al.* (2012) good adaptation to fluctuating light levels and avoiding or tolerating silica limitations (species is heavily silicified) allow *A. normanii f. subsalsus* to spread. KAŠTOVSKÝ *et al.* (2010) pointed out that the expansion of this species is probably explained by eutrophication of surface waters.

The aim of this study was to collect information on the distribution and ecology of *A. normanii f. subsalsus* and *A. normanii f. normanii* in Serbia. Also, we want to obtain a wider data basis for better characterisation its ecological preferences. These new information are important for further prediction of diatoms as bioindicators, and river monitoring programs.

MATERIAL AND METHODS

The material was collected from 5 localities which are located in the northern part of Serbia, in the Pannonian Plain: Tisza River, Veliki Bački Canal, Danube–Tisza–Danube Canal (Kajtasovo), Ponjavica River (Brestovac) and Omoljica). Samples from Tisza River, Veliki Bački Canal were collected in 1997, from Danube–Tisza–Danube Canal (Kajtasovo), Ponjavica River (Brestovac and Omoljica) in 2002 and again from Ponjavica River (Omoljica) in 2006. Diatom species were collected from three different communities: phytoplankton, phytobenthos and epilithic. *A. normanii* f. *subsalsus* was found in phytoplankton and phytobenthos samples at all localities. Chemical analysis of water was examined at the Institute of Public Health of Serbia “Dr Milan Jovanović Batut” and Serbian Hydrometeorological Institute.

Diatom samples were treated following standard methods to obtain permanent slides (KRAMMER and LANGE-BERTALOT 1986). After this process the material was air dried on cover glasses and mounted in Naphrax® mounting medium. Permanent slides, prepared material and aliquots of the samples were deposited in the diatom collection of the University of Belgrade, Faculty of Biology. Light microscope micrographs were obtained by Zeiss Axio Imager M.1 microscope with DIC optics and Axio Vision 4.8 software. Terminology of valve morphology and identification is based according KRAMMER and LANGE-BERTALOT (2004). The abundance was estimated by counting 400 valves of each taxa present on the slide and by counting the percentage of valves.

RESULTS AND DISCUSSION

Here we present the descriptions and distribution of the invasive *A. normanii* f. *subsalsus* found in the Serbian part of the Pannonian Plain.

Actinocyclus normanii (W. Gregory ex Greville) Hustedt 1957 f. *subsalsus*
(Juhlin-Dannfelt) Hustedt 1957 (Hemidiscaceae, Coscinodiscales)
(Fig. 1A–G)

Morphological characteristics

Valves are circular; one valve is concave and other more convex in the middle. The diameter ranges from 15.85–29.26 μm . Valves are with patterns of radiating parallel rows of areolae which are organized into sectors. The numbers of areolae are 11–12 in 10 μm and maintain constant throughout the valve. Characteristic

morphological feature of the valve is ring of rimoportulae (Fig. 1 (A–C)), located on the internal side of valve. The species can occur as single cells or as colonies.

According to KRAMMER and LANGE-BERTALOT (2004) the valve diameter is 16–58 μm . KIPP *et al.* (2012) present populations with valve diameter 16–47.5 μm .

Distribution

New data on distribution in Serbia (with UTM grid codes in brackets): Tisza River (DR25), Veliki Bački Canal (CR38); Danube–Tisza–Danube Canal (Kajtasovo, EQ17), Ponjavica River (Brestovac, DQ85) and Ponjavica River (Omoljica, DQ75) (Fig. 2).

Actinocyclus normanii (f. *subsalsus*) was found in phytoplankton and phyto-benthos communities in relative abundances from 0.20–16.25 % (Table 1).

Europe: Germany (HASLE 1977, KISS *et al.* 1990, LUDWIG and SCHNITTLER 1996, TÄUSCHER 2014), Hungary (KISS *et al.* 1990, KISS *et al.* 2012), France (KISS *et al.* 1990), Britain (BELCHER and SWALE 1979, HARTLEY *et al.* 1986, HARTLEY *et al.* 1996, WHITTON *et al.* 2003), Russia (KISS *et al.* 1990, GENKAL 1992, KORNEVA 2003, TARASOVA and BURKOVA 2005, KORNEVA 2007, BELYAEVA 2011), Poland (STACHURA and WITKOWSKI 1997), Slovakia (HINDAKOVA 1994), Baltic Sea (LIUKKONEN 1997, HÄLLFORS 2004, LANGE 2010), Turkey

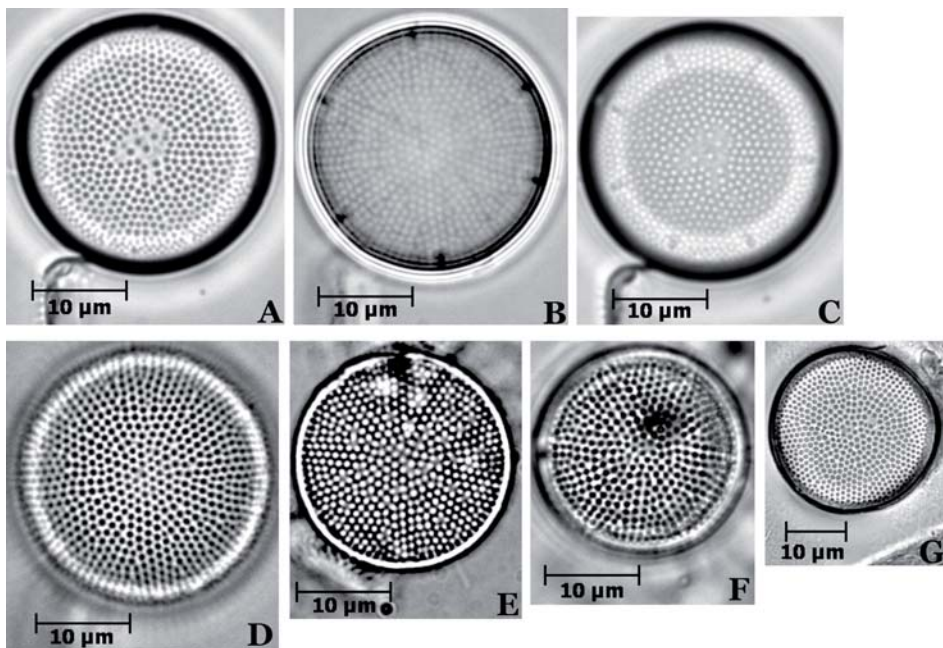


Fig. 1A–G. LM micrographs of the *Actinocyclus normanii* (f. *subsalsus*).

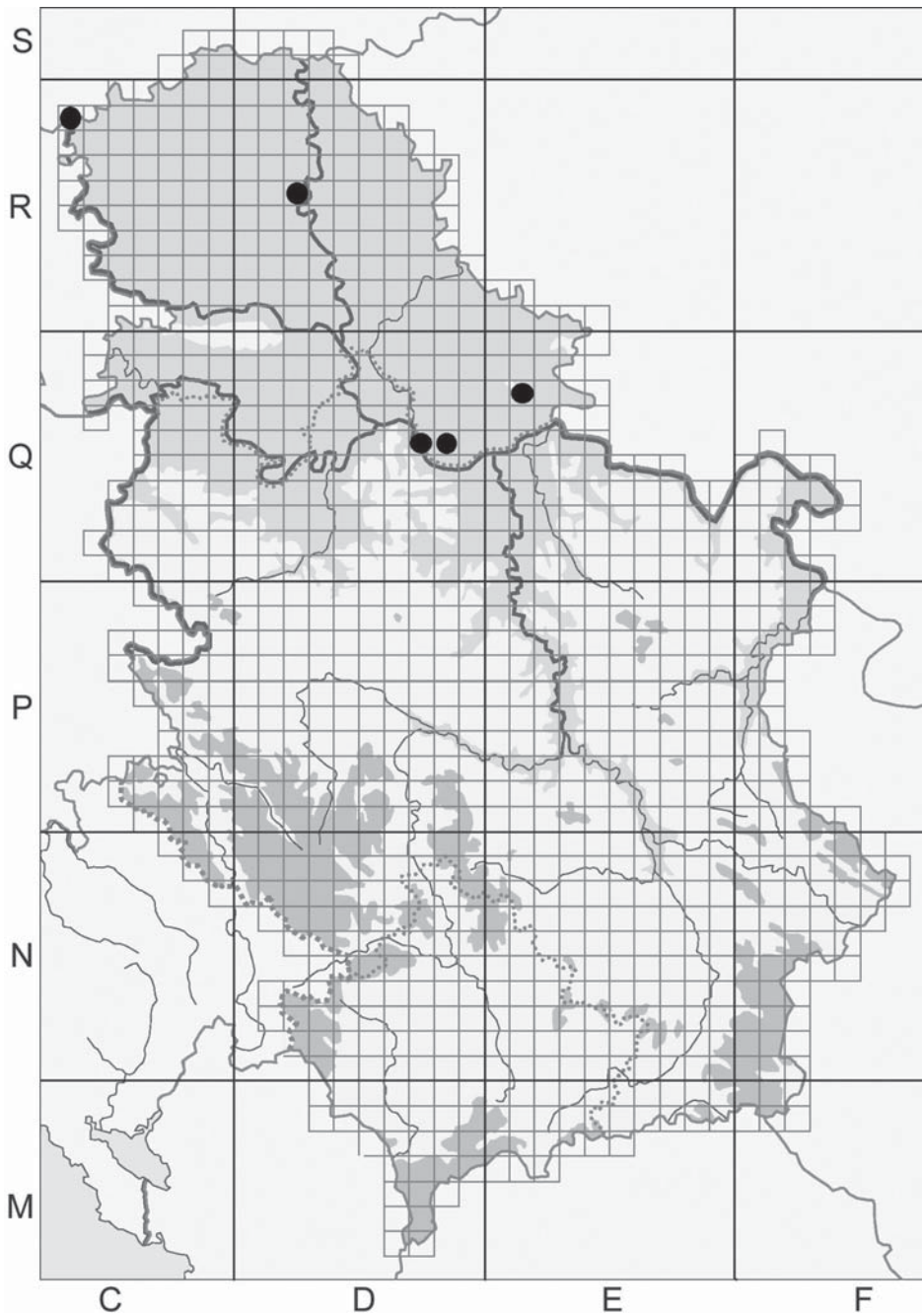


Fig. 2. UTM map of Serbia with new data on distribution of *Actinocyclus normanii* (f. *subsalsus*).

(Europe) (AYSEL 2005), Czech Republic (KISS *et al.* 1990, KAŠTOVSKÝ *et al.* 2010), Netherlands (DIJKMAN and KROMKAMP 2007), Albania (KUPE *et al.* 2010), Macedonia (LEVKOV and WILLIAMS 2012), Spain (PÉREZ *et al.* 2009), Romania (CARAUS 2002, CARAUS 2012). (Fig. 3)

Atlantic Islands: Canary Islands (AFONSO-CARRILLO 2014), Faroe Islands (WITON and WITKOWSKI 2006).

North America: Great Lakes (STOERMER *et al.* 1999, KIPP *et al.* 2012), NW USA (BAHLS 2009), United States of America (MARSHALL 2005, KOCIOLEK 2005, EBERLE 2008). (Fig. 3).

South America: Argentina (RODRIGUEZ *et al.* 2006, GÓMEZ *et al.* 2009), Brazil (ESKINAZI-LEÇA *et al.* 2010), Colombia (LOZANO-DUQUE *et al.* 2011, MONTOYA-MORENO *et al.* 2013). (Fig. 3).

Asia: Russia (Far East) (MEDVEDEVA and NIKULINA 2014), China (LIU 2008), Israel (BARINOVA *et al.* 2008), Korea (JOH 2010), Japan (TANAKA 2014). (Fig. 3).

Australia and New Zealand: Australia (BOSTOCK and HOLLAND 2010, MCCARTHY 2013), New Zealand (HARPER *et al.* 2012).

Ecology

Actinocyclus normanii (f. *subsalsus*) from our samples occurs in waters with moderate to high conductivity (348–918 $\mu\text{S}/\text{cm}$), pH ranges from 8.0–8.83, at a water temperature between 8.0–25.7 °C with a maximum abundance at 16.2 °C (Table 1).



Fig. 3. The worldwide distribution of *Actinocyclus normanii* based on our studies and literature sources (see above).

Table 1. Ranges of physical and chemical parameters of the localities where *Actinocyclus normanii* (f. *subsalsus*) occurred.

Sampling sites/ Parameters	Tisza River	VB Canal	DTD Canal	Ponjavica River	Ponjavica River	Ponjavica River
			Kajtasovo	Brestovac	Omoljica	Omoljica
Year	1997	1997	2002	2002	2002	2006
Temperature (°C)	16.5–21.0	8.0–25.7	16.2	9.2	10.2	22
pH	7.8–7.9	8.0–8.5	8	8.83	8.05	8.6
Conductivity (µS/cm)	222.4–361.3	620–746.6	348	807	918	890
N-NH ₄ ⁺ (mg/l)	0.23–0.61	0.07–0.50	0.38	0.38	0.38	1,6
N-NO ₃ ⁻ (mg/l)	1.37–1.70	0.05–1.55	1.2	0.36	0.33	<0.5
TP (mg P/l)	0,2	0.18–0.39	0,13	0.08	0.83	0.43
Cl ⁻ (mg/l)	24.1–24.7	29.4–52.6	23	ND	ND	78
SO ₄ ⁻² (mg/l)	57–64	44–100	39	ND	ND	90
Relative abundances (%)	+	+	0.20–16.25	0.31	+	0.42–0.61
Substratum	PP	PB	PP	PP	PP	PP, PB

Abbreviations: VB Canal: Veliki Bački Canal, DTD Canal: Danube–Tisza–Danube Canal, PP: phytoplankton, PB: phytobenthos, +: recorded, ND: no data.

According to the literature data *Actinocyclus normanii* (f. *subsalsus*) is a cosmopolite, planktonic, phytobenthic, alkalibiontic and halophytic species, which occurs in waters with moderate to high conductivity and it is indicator of eutrophied, polluted waters (KORNEVA 2003, KRAMMER and LANGE-BERTALOT 2004, KAŠTOVSKÝ *et al.* 2010, KISS *et al.* 2012, KIPP *et al.* 2012). Populations in the Great Lakes had shown a maximum abundance at a water temperature around 20 °C (KIPP *et al.* 2012).

CONCLUSIONS

The presence of many diatom taxa could give evidence of a wide scale of the environmental possibilities for their development within the studied area. Identification of invasive algae species in water bodies is possible through the long-term floristical studies and continuous biomonitoring of surface waters. Therefore, we continue to monitoring the occurrence of invasive taxa in the waters of Serbia.

* * *

Acknowledgements – Financial support was provided by the Ministry of Education and Science of the Republic of Serbia (Projects No. TR 037009).

Összefoglaló: Az *Actinocyclus normanii* egy tengerekben és brakkvizekben honos algafaj, mely édesvizekben megjelenve a világ számos pontján invazívá vált. Terjedésének kedvez, hogy kiválóan tolerálja a váltakozó fényviszonyokat és az eutróf viszonyokat. Két alakját különböztetik meg a tengerekben élő *f. normanii*-t és az édesvizekben előforduló *f. subsalsus*-t; azonban a két alak közti pusztán méretbeli eltérés miatt ez a különbségtétel nem általánosan elfogadott. Jelen közlemény elsőként tudósít a *f. subsalsus* szerbiai megjelenéséről, bemutatja a faj aktuális elterjedését Szerbiában és világszerte. A faj Szerbiában 1997 óta jelen van a Pannonicum területén: a Tiszában, a Bácskai-Nagy-csatornában, a Duna–Tisza–Duna-csatornában és a Panyóca folyócskában, további terjedése Szerbiában vizsgálat tárgyát képezi.

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(submitted: 06.10.2016, accepted: 18.11.2016).