Short Communication

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Algae of the genus *Volvox* (Chlorophyta) in sub-extreme habitats

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ABSTRACT

Literature data on the life of green colonial algae of the genus *Volvox* (Chlorophyta) in sub-extreme habitats (polar, sub-polar and mountain regions) are critically considered. Very few species (primarily homothallic *Volvox aureus*) are able to thrive in such conditions.

Keywords : Geographical distribution, reproduction, sub-extreme habitats, *Volvox*.

The genus *Volvox* Linnaeus (Volvocaceae, Chlorophyta) includes more than 20 species of freshwater flagellate algae (Nozaki *et al*. 2015), providing an opportunity to study the developmental mechanisms in a relatively simple system consisting of two cellular types (somatic and reproductive). *Volvox carteri* f. *nagariensis* Iyengar is a valuable model of developmental and cell biology (Prochnik *et al*. 2010, Matt and Umen 2016, Desnitskiy 2017). However, this note is devoted to a topic that usually does not attract the attention of *Volvox* researchers – an analysis of some aspects of the ecology and geographical distribution of this algal genus.

Data on the geographical distribution of all representatives of the genus *Volvox* (Desnitskiy 2008, 2016) were collected. Only *V. aureus* Ehrenberg is a truly cosmopolitan species. Several *Volvox* species were reported from several continents each: for example, *V. africanus* West, *V. carteri* Stein, *V. globator* Linnaeus and *V. tertius* Meyer. A number of species is characterized by local distribution: for example, *V. gigas* Pocock, *V. powersii* (Shaw) Printz, *V. spermatosphaera* Powers. It turned out that in the relatively high latitudes of the Northern Hemisphere (northward of 52–57° N), only *V. aureus*, *V. globator* and *V. tertius* occur. It is interesting to note that precise data on findings in the Arctic (northward of the Arctic Circle) are available only for *V. aureus* (Ermolaev *et al*. 1971, Sheath and Hellebust 1978, Sheath and Steinman 1982), although the distribution areas of *V. globator* and *V. tertius* approach the Arctic Circle (e.g., Komarenko and Vassilyeva 1978). The most northern record of *Volvox* (*V. aureus*) was made at about 80° N on Ellesmere Island in Canada (Sheath and Steinman 1982). In the Southern Hemisphere, the most southern finds of *Volvox* (*V. aureus* and *V. tertius*) were made approximately at 54° S in Chile on the island of Tierra del Fuego (Parra *et al*. 1983). There are currently no data on *Volvox* in Antarctica, though the colonial volvocine algae *Tetrabaena socialis* (Dujardin) Nozaki et Itoh and *Pandorina* sp. were recorded on this continent (Nozaki and Ohtani 1992).

High altitude conditions— The recent report made by Fritz *et al*. (2015) about the discovery of *Volvox* in the mountains of Peru (South America) at the elevation of more than five thousand meters above sea level seems to be doubtful. The illustration from this article (which focuses mainly on diatoms) shows a spherical colony with a diameter of about 14 μm, consisting of several hundred very small cells (Fritz *et al*. 2015, p. 373, Fig. 5A). However, it must be recalled that the colonies of all *Volvox* species are much larger, and the small spherical colonies described by these authors may be actually characteristic of various groups of colonial microorganisms.

The maximum elevation at which *Volvox* sp. was actually recorded is 3812 m above sea level (alpine Lake Titicaca in South America) (Rada 2003). Besides, the literature contains quite reliable information about the occurrence of *V. aureus* population in early September 1969 in a small mountain lake in Colorado (USA) at the altitude of about 3200 m at water temperature of 15° C and pH of about 6.5 (Whitford and Kim 1971). The maximum elevation at which *V. globator* was found (also in the mountain lakes of Colorado) is 2500 m above sea level (Olive 1953). In the state of Arizona (USA), the maximum altitude at which *V. aureus* and *V. globator* were found was 2530 and 2070 m, respectively (Taylor and Colton 1928). It is also necessary to cite a study in which *V. aureus* was found in puddles formed in early summer after snow melt at the altitude of 2600 m in the mountains of Tajikistan, Central Asia (Kisselev and Vozhennikova 1950). I am not aware of records of other *Volvox* species in any areas of the Old and New Worlds at the elevations more than 2000 m above sea level.

Thus, it seems that *V. aureus* and *V. globator* are the "most successful" representatives of the genus *Volvox*, penetrating high into the mountains, and only these species (together with *V. tertius*) penetrate the subarctic regions. Note, however, that *V. aureus*, *V. globator* and *V. tertius* also occur in temperate, subtropical and tropical latitudes. It is noteworthy that all these three species of *Volvox* are homothallic (sexual reproduction is possible within a clone) (Darden 1966, Starr 1968, Starr and Zeikus 1993), although, of course, there are other homothallic species (e.g., *V. barberi* Shaw or *V. spermatosphaera*) that were not found in high mountains or

high latitudes. On the other hand, some heterothallic species of *Volvox* (with separate male and female clones) can be quite widespread in the tropics and subtropics. For example, *V. rousseletii* West is distributed throughout Africa (from South Africa to Egypt) (Smith 1944), but was also found in Japan (Kimbara *et al*. 2019).

It is important to note that *Volvox* from the Arctic, subarctic and highland regions was never studied in laboratory cultures. However, such studies will be of great interest and particularly concerning *V. aureus*, the only cosmopolitan representative of the genus. This species encompasses not only strains with the formation of sexual colonies and dormant zygotes (Darden 1966, Starr and Zeikus 1993), but also strains where sexual colonies do not form and dormant stages are represented by parthenospores (Darden 1968, Starr and Zeikus 1993). In this connection it would be intriguing to analyze the reproductive features in the highland and polar populations of *V. aureus*. Finally, it is appropriate to remark that the application of molecular identification methods may delimit *V. aureus* into two related species in the future. Such a delimitation was recently made in the case of "*V. africanus*" (Nozaki *et al*. 2015). Unfortunately, then phycologists would not be able to use the numerous earlier records of "*V. aureus*" based on the morphological characters to review the geographical distribution of *V. aureus* sensu stricto and a new *Volvox* species.

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