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Communication

Algal Bloom Occurrence and Effects in Russia

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Abstract: Eutrophication caused by the entry of nutrients into a water body may lead to algal bloom. Russia possesses the world's second highest supply of renewable freshwater resources and has faced the problem of eutrophication for many years. Nevertheless, as far as we know, no general analysis of Russia's algal bloom situation has been before carried out. We have analyzed mass media and scientific reports about algal outbreaks from 2016 to 2018, which allowed us to determine the geographical distribution of algal blooms in Russia, as well as the major effects of eutrophication. As a result, we showed that algal blooms happened in all major climate zones and all federal districts. Cyanobacteria are the most frequently reported photosynthetic organisms comprising algal blooms in freshwater reservoirs located in the continental part of Russia and in the Baltic Sea. Dinoflagellate dominated blooms are more characteristic for the coastal parts of the northeastern Pacific Ocean. The largest number of reports comes from the south of the European part of Russia. However, we did not find significant correlations between state statistics data on factors possibly affecting eutrophication (e.g., population, arable land area, fertilizers, livestock, air temperature, etc.) and the number of algal outbreaks in the regions. Mass media analysis showed that algal blooms attract considerable public attention in Russia, which requires the scientific community to actively participate in solving the problem.

Keywords: eutrophication; algal bloom; Russia; monitoring

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1. Introduction

Eutrophication is "the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned" [1]. Eutrophication is becoming one of the largest problems associated with the quality of water in lakes and coastal zones of the seas adjacent to areas with a large population [2–4]. According to a survey of the world's lakes, conducted in the early 1990s, 54% of Asian lakes, 53% of European lakes, 48% of lakes in North America, 41% of lakes in South America, and 28% of lakes in Africa were subject to eutrophication [5]. In recent years, the algal bloom intensity in water bodies continues increasing worldwide. The analysis of satellite data shows that the situation has worsened over the past 30 years in 68% of large reservoirs [6]. At the same time, the number of water bodies with a low trophic level is rapidly declining. For example, in the United States the number of oligotrophic reservoirs decreased from 25% to 7% between 2007 and 2012 [7].

The bloom of toxic species of microalgae and cyanobacteria (Harmful Algal Blooms) causes serious environmental, social, and economic damage including a poisoning of humans and animals [8,9].

A conservative estimate of annual economic loss in the United States due to the eutrophication of freshwater bodies is 2.2–4.6 billion dollars [10,11]. With a further increase of the world population and anthropogenic pressure on water bodies, further deterioration of their condition is predicted. Due to the growth of livestock waste, the use of fertilizers, increased erosion, and inflow of contaminated wastewater, the productivity of water bodies is expected to increase by 1.37–3.1 times. Thus, the problem of eutrophication will only grow worse [12].

Russia possesses the world's second renewable water reserves after Brazil [13]. A significant number of scientific publications as well as reports in the mass media show that the problem of eutrophication is widespread in Russia [14–20].

Nevertheless, no general assessment of the problem of eutrophication in Russian water bodies has been conducted so far. The lack of an up-to-date assessment of the situation prevents the introduction of changes in state policy aimed at reducing the severity of the problem of eutrophication. Currently, the most effective method for assessing the situation is to conduct a broad study by qualified specialists using standardized methods. The National Lakes Assessment by United States Environmental Protection Agency [21] can serve as a model. It includes chlorophyll *a* content and cyanobacterial toxins analysis, as well as a number of other significant parameters. In Russia, state monitoring of the water resources does not include a specialized assessment of the trophic status of lakes and outbreaks of algal blooms [22]. In this situation, the scientific community can use other methods to assess the general situation concerning the ecological status of reservoirs throughout the country. Each method has its own strengths and weaknesses. For example, satellite surveillance allows to obtain instrumental data with a high frequency and geographical coverage but can only be effectively used to monitor reservoirs more than several square kilometers large [6,23]. Monitoring smaller water bodies requires the use of unmanned aerial vehicles or ground-based observations, which in turn requires a fairly dense monitoring network. In the case of Russia, this is hindered by the large territory and uneven distribution of the population over the territory. The analysis of scientific publications allows getting high-quality information about the ecological status of water bodies. Nevertheless, scientific publications are usually limited to a small number of regions or lakes where studies are conducted.

In order to obtain preliminary information on outbreaks of microalgae and cyanobacteria, we used an approach based on the analysis of mass media and scientific publications about cases of algal blooms. The data obtained were collected on Cyanohab.ru website [24] which was specially developed by us in order to collect the most recent information about algal blooms in Russia and to analyze their geographical distribution. The goal of this article is to analyze and systematize reports on algal blooms in Russia from various sources for the period from 2016 to 2018, and to make preliminary conclusions on the patterns of eutrophication problem in Russia.

2. Materials and Methods

Mass media monitoring of algal blooms reports was carried out using the Yandex News [25], the automatic news processing and systematization service developed by Yandex N.V. As of 31 October 2019, the service database contains 7076 sources of information including various types of media and thematic Internet sites. News processing is carried out in real-time and a news archive since 2000 has been available. The search for information on algal blooms was carried out using the search query "vodorosli" ("algae" in Russian) as providing the widest coverage of sources. News regarding the problem of algal blooms were selected from the information received and irrelevant news were excluded. The news articles retrieved were about the outbreaks of algal blooms that occurred from 1 January 2016 until 31 December 2018 on the territory of Russia and Russian territorial waters. Articles were excluded from the analyses for any one of the following reasons: (1) the articles were devoted to other topics than algal blooms, for example, the use of algae in food, biotechnology, medicine, etc.; (2) the outbreaks were not located on the territory of Russia; (3) the outbreaks occurred before or after the defined period of time; (4) there was insufficient published data for determining the location of the outbreak; or (5) there was not enough data to consider the event as the algal bloom, for example, fish or bird mortality without noting the mass development of algae. Information from various sources about algal blooms in a particular locality was combined into one file, which was further considered as one case. The file includes information about the name and the location of the reservoir, the region of Russia where the reservoir is located, the year of the outbreak, a link to information sources, text with notes and quotes from information sources that carry significant data. Significant data are data that include information on the type of dominant photosynthetic organisms, possible causes of the outbreak, the observed environmental, social and economic consequences of the outbreak, proposed or ongoing actions to reduce damage, quotes from qualified experts, information on outbreaks previously observed in this reservoir. Then, the analysis of the obtained database was carried out.

Moreover, an electronic literature search was conducted via Google Scholar [26] and Elibrary.ru [27] (the former is the database of the scientific publications in Russian) to identify reports about algal blooms in Russia published after 1 January 2016. An initial search on Elibrary.ru used the identifiers "vodorosli tsvetenie", "vodorosli evtrofikaciya", "cyanobacterii massovoye razvitie", "cyanobacterii tsveteniye", "vodorosli massovoye razvitie" ("algae bloom", "algae eutrophication", "cyanobacteria massive growth", "cyanobacteria bloom", and "algae massive growth" in Russian). Titles and abstracts were reviewed and six full-text articles that met the inclusion criteria were retrieved. An initial search on Google Scholar used the identifiers "algae bloom Russia", "algal bloom Russia", "algae eutrophication Russia", "cyanobacteria massive growth Russia", "cyanobacteria bloom Russia", "algae massive growth Russia", and "blue green bloom Russia". The Google Scholar search was performed using "Publish or Perish" software [28]. The results of the searches were saved in the CSV format tables and compared for elimination of duplicate rows. Titles and abstracts were reviewed and five full-text articles that met inclusion criteria were retrieved. The scientific articles retrieved were about the algal blooms on the territory of Russia and Russian territorial waters that occurred from 1 January 2016 until 31 December 2018. Articles were excluded from the analyses for any one of the following reasons: (1) the articles were devoted to other topics than algal blooms, for example to study of single isolates of algae or cyanobacteria; (2) the authors of the publication don't consider the event as the algal bloom; (3) the outbreaks occurred before or after the defined period of time; (4) the outbreaks were not located on the territory of Russia.

Links to the sources of information, year and geographic information were stored at Cyanohab.ru web-site database [24]. As of 31 October 2019, the website database contained information on 134 algal blooms. The information on 60 outbreaks reported in mass media and 11 outbreaks reported in scientific articles that occurred from 2016 to 2018 was selected from the database for analysis of the factors affecting the algal outbreak.

In this study, the lakes that could fit a 5 km × 5 km cell filter were considered as large. This filter could exclude water bodies that were too small or irregular for reliable detection and mapping with the use of remote-sensing mapping [23].

The statistical information was taken from the Federal State Statistic Service [29,30]. The statistics on the average resident population was obtained in the Demographics section [31]. The statistics on the agricultural data (arable land area, livestock number including cattle, cows, pigs, and poultry, as well as fertilizers applied including both organic and inorganic) was obtained in the Enterprise economy section [32,33]. The data on the average air temperature in July were obtained from the Russian Statistical Yearbook and from the Federal State Statistic Service, Environment section [34–36]. Information on Köppen–Geiger climate zones was obtained using the map downloaded from [37,38]. Climate zones map and Cyanohab.ru data were opened using Google Earth Pro software as separate layers [39].

Correlation analysis was carried out on the level of regions and federal districts. The data were tested for normality of distribution (Shapiro–Wilk test, $\alpha = 0.05$). Pearson's correlation together with two tailed p-value ($p < 0.05$) was used to determine the relationship between the number of algal blooms and mean values of the resident population, arable land area, number of cows, pigs, poultry, amount of organic fertilizers, amount of inorganic fertilizers applied, air temperature in years

2016–2018. Calculations were made using a Python environment for scientific computations (SciPy and Numpy) and table editing [40,41].

3. Results

3.1. Geographical Distribution of Algal Blooms in Russia

The analysis of the geographical distribution of algal bloom cases shows that they occur in all major climate zones of Russia from polar to warm temperate and arid (Figure 1). Algal blooms were observed in freshwater and marine water bodies, both in the European and Asian part of the Russian Federation.

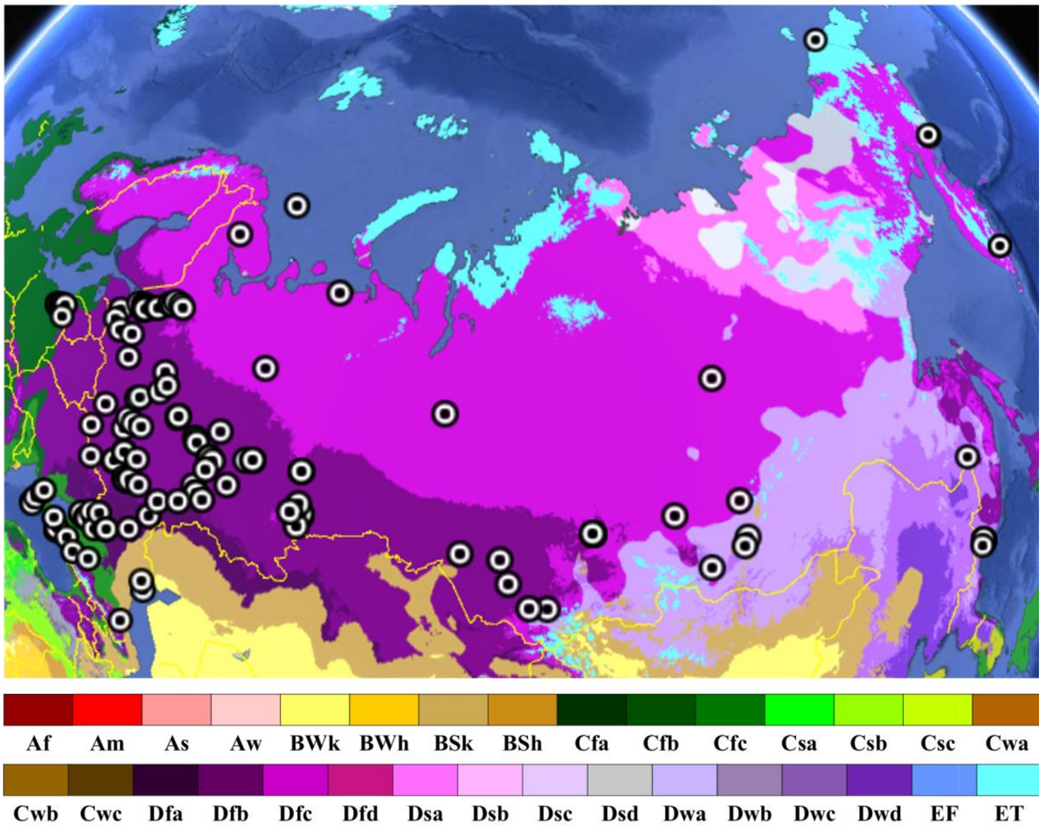

Figure 1. The map of the geographical distribution of algal bloom outbreaks in Russia. The map was created using Google Earth Pro software [39], Cyanohab.ru data for algal bloom outbreaks (black and white circles) and Köppen-Geiger climate map [37,38]. The legend below shows the types of the climate zones [38]. Climate zones with the first letter "E" in the abbreviation represent polar climate, "D" represent boreal climate, "C" represent warm temperate climate, "B" represent arid climate. More information about types of the climate zones is available at http://koeppen-geiger.vu-wien.ac.at/present.htm [37].

The largest number of algal outbreaks among the federal districts of the Russian Federation in 2016–2018 (Figure 2) was reported in the Southern Federal District (21%). It is a densely populated region with the warmest climate and developed agriculture. The Central and Volga (18% and 15%) Federal Districts were in the second and third places, respectively. These regions are also densely populated and have developed industry and agriculture. Besides, we cannot exclude a possibility that the local population and mass media in these regions are more concerned about the problem of algal blooms that results in a higher number of reports. Algal blooms were also observed in regions with a colder climate and lower population density: Northwestern (11%), Ural (10%), Siberian (11%), and Far Eastern Federal Districts (12%). The smallest number of reports on algal blooms was recorded in the North Caucasus Federal District (1%). This fact can be explained by the mountainous terrain with a high flow rate in rivers and water bodies or by a lack of significant public awareness about the problem of eutrophication.

Figure 2. The map of the algal bloom outbreaks in Federal Districts of Russia in 2016–2018. The intensity of green color shows the relative number of algal blooms in the Federal District. Lines show the borders of the Federal Districts of Russia: 1—Central, 2—Northwestern, 3—Southern, 4—North Caucasian, 5—Volga, 6—Ural, 7—Siberian, 8—Far Eastern. Borders of the Federal Districts are shown as of 4 November 2018.

We analyzed the correlation between the number of algal blooms in federal districts and regions of the Russian Federation in 2016–2018 and various statistical indicators (average resident population, arable land, inorganic and organic fertilizers used by agricultural organizations, and livestock numbers including cows, pigs, and poultry) (Table S1, Table S2). The Shapiro–Wilk test showed that all variables had a normal distribution except for the number of pigs in farms that was excluded from the further analysis. However, we did not find a reliable relationship between the number of algal blooms and the analyzed parameters using the Pearson correlation method. The correlation range was from 0.13 to 0.63, while the p-value was in the range 0.09–0.74.

3.2. Description of Outbreaks in Mass-Media

The analysis of media reports showed that the expert estimates by scientists are given in 26% of cases. In a large number of cases (43%), the opinion of government officials (Prosecutor's office, Federal Service for the Supervision of Natural Resources, Federal Service on Surveillance for Consumer Rights Protection and Human Well-being, municipal and regional authorities) is given.

Most of the water bodies for which information on the algal blooms was obtained were small in size. Their share was 59% of the total number of cases. Large reservoirs for which satellite analysis methods are applicable accounted for 41% of the sample. Previous outbreaks in the same reservoir are mentioned in 22% of cases, indicating the recurrence of the problem.

In 76% of cases, the possible causes of algal blooms are given. In most cases, the anthropogenic factors are mentioned as the main cause of algal outbreaks (42%). Among them, the focus was on effluents from municipal treatment facilities (18%). Effluents from industrial enterprises account for 16%, effluents from agriculture or tourism each comprise 4%. Natural causes are less frequently mentioned than anthropogenic ones (29% of cases). Among the natural causes, the hot weather (15%) and shallowing of the reservoir (13%) are noted.

The analysis of media reports shows that the dominant types of photosynthetic organisms were named in 70% of cases. Moreover, the largest number of references was associated with cyanobacteria (40% cases). The references on the outbreak of macrophytes are in second place. Some reports cited interviews with scientists. In these cases, the articles may have provided information on taxonomic groups of microalgae and cyanobacteria. According to these reports, in freshwater reservoirs the cyanobacterial growth of the genera *Microcystis*, *Anabaena*, *Aphanizomenon*, and *Dolichospermum* was reported to cause the greatest problem. These genera dominated in algal blooms registered in пресноводных водоемах вdifferent regions of Russia. The outbreak of *Alexandrium* microalgae was detected in the Pacific Ocean. The mass media reported also about *Nodularia* cyanobacterial blooms in the Baltic Sea. Also, a unique case was recorded in 2018 in the village of Syreika, Samara Region. An outbreak of purple sulfur bacteria *Thiolamprovum* sp. occurred in artificial storage ponds near an industrial area comprised by several brewing companies [42,43].

3.3. Reported Effects of Algal Blooms

The media coverage mainly concerns the social consequences of the eutrophication of water bodies (72% of cases). First of all, the poor quality of water is mentioned, causing unwillingness (18%) or an inability to swim in the reservoir (9%). A relatively high number of cases (16%) express concern over the possible presence of toxins in the water. The third group of negative consequences of algal blooms attracting the attention of the media is a decrease in the tap water quality (15%) or the cessation of water supply to the population (2%), as well as a bad smell from the reservoir (11%).

The negative environmental consequences of eutrophication of water bodies are mentioned less often than social problems (35% of cases). Mainly they refer to the problems associated with the death of fish or birds (33%). It should be noted that the death of fish or birds in many cases becomes the main fact that the media draws attention to and is often mentioned in the article headings. Among the environmental consequences, flooding of part of the territory caused by clogging of drainage pipes with algae is also reported.

Economic losses caused by the outbreaks of algae are mentioned in 20% of cases. Basically, losses are estimated as direct costs associated with the reconstruction of obsolete water supply and wastewater treatment systems.

Only 30% of cases mention any measures taken to solve the problem of algal blooms in reservoirs. Among them, 13% of cases mention the necessity to take measures, 4% provide information on planning the measures to solve the problem, and 13% of cases report about actual events.

3.4. Description of Outbreaks in Scientific Articles

We have found references to only 11 cases of algal outbreaks in the reservoirs of Russia in 2016–2018 in the scientific articles [44–54]. In that time, four cases happened in 2016, six in 2017. Only one report presented on a conference described an outbreak in 2018 [48]. This distribution is probably due to the fact that the preparation of a research article takes much more time than the communication in mass media. A small number of scientific articles does not yet allow us to directly compare the data obtained from mass media analysis and from scientific articles. Nevertheless, some preliminary conclusions can be drawn.

The majority of articles (10 out of 11) focused on the cyanobacteria dominated blooms in freshwater reservoirs and the mediterranian Baltic and Azov Seas with relatively low salinity level [45–54]. *Planktothrix agardhii*, *Planktolyngbya limnetica*, *Aphanizomenon flos-aquae*, *Microcystis aeruginosa*, *Dolichospermum spiroides*, and *Dolichospermum lemmermanii* were noted among the dominating species in freshwater reservoirs. The cyanobacterium *Nodularia spumigena* dominated in the bloom in the Baltic Sea. Besides, the colonies of *Anabena sp.*, *Merismopedia sp*, *Planktothrix sp.*, and *Aphanizomenon flos-aquae* were detected [48]. One article focused on "Red tide" events that happened next to the Pacific coast on the Far East of Russia with a dinoflagellate *Alexandrium fundyense* as a dominant species [44]. According to the opinion of the authors of scientific articles, the main reasons for the outbreaks were natural phenomena, e.g., hot weather and changes in hydrodynamic characteristics of the reservoirs (5 out of 11). Anthropogenic causes (contaminated wastewater flow) were mentioned in 2 cases out of 11.

The determination of toxins concentration was conducted in three cases [44,46,47]. On August 2016, the algal bloom and the mass mortality of fish (gibel carp *Carassius gibelio*) and waterfowl (mallard *Anas platyrhynchos*) were detected in the Kazanka River (the tributary of the Volga River). The cyanobacteria *Planktolyngbya limnetica* and *Aphanizomenon flos-aquae* dominated in the samples. The content of cyanotoxins in water according to the results of ELISA was 1.4–12.1 μg/L (microcystins) and 0.057–0.294 μg/L (anatoxin-a). The content of microcystins (1.96–3.16 μg/kg) and anatoxin-a (1.56–5.21 μg/kg) in fish and duck muscles were also determined [46].

In September 2017, the area of discolored water 50 m wide and 30 m long was found close to the dam of the Irkutsk hydroelectric power station near Lake Baikal. Analysis of samples showed that discolored water was a result of a *Dolichospermum lemmermannii* bloom, followed by its decay and release of saxitoxin and nutrients. sxtA gene was amplified from the samples. Water from the polluted area contained 600 ± 100 μg/L saxitoxin as measured by HPLC-MS (Agilent technologies, Inc., CA, USA). Immunoassay analysis (ELISA) showed a concentration of saxitoxins in the water of 2900 ± 900 μg/L [47].

In July 2017 a red tide occurred in Olyutorskiy Bay, Bering Sea. Fishermen reported that the pink salmons (*Oncorhynchus gorbuscha*) caught in the bloom area were slack, looked tired and died soon in the trap net. The water samples contained a suspension of *Alexandrium* cells. The concentration of saxitoxin determined using an immune-enzyme assay (test-system RIDASCREEN® FAST PSP SC) reached 330 μg/L [44].

The main negative effects mentioned in the scientific articles are foul smell of the water (3 cases out of 11), toxins presence in water (3 cases out of 11), fish and bird kill (2 out of 11), unwillingness to swim in a reservoir (1 case) and deterioration of tap water quality (1 case).

It should be noted that in 3 cases out of 11 the scientific articles mentioned the direct appeal to the scientists by the representatives of the society or business. Among them there were the appeals of Irkutsk hydroelectric power station administration concerned by the risk of contaminated water flow into the urban water system, as well as the appeals of the fishermen worried by the unusual behavior of pink salmon [44,47]. Besides, the reason for the scientific research may be the appeal of the local environmental authorities as a result of the population's concern about the water color change in the reservoir [50]. In some cases, there was no mention about the local population requests or information from mass media in the scientific publication, but actually the research was initiated by the information from the community: for example, the authors of this article took part in the *Dolichospermum lemmermannii* bloom study on Lake Baikal in 2016 [54]. The information about the bloom came to the authors through several channels, including the direct appeal of the local residents, mass media, and social networks. However, the article describing the bloom contains only the mention that "cyanobacterial bloom of a green color a few kilometers in size with a bad odor was discovered by local people", but no particular way of the information transfer is given [54].

4. Discussion

4.1. Algal Bloom Occurrence in Russia

Our results show that algal blooms are widespread in Russia and occur on the territory of all major climate zones and federal districts. Cyanobacteria are the most frequently reported photosynthetic organism during algal blooms in freshwater reservoirs located in the continental part of Russia and in the Baltic Sea. Dinoflagellate dominated blooms are more characteristic for coastal parts of the northeastern Pacific Ocean [44]. The highest number of algal bloom reports come from the Southern federal district. This can be explained by a combination of natural and anthropogenic factors, such as a warm climate, well developed agriculture and tourism, low flow rate of rivers and reservoirs, but also it can be explained by a higher attention of local population and mass media to the problem.

We did not find a significant correlation between reports about algal blooms in Russia and statistical data on factors that may influence the eutrophication process (arable land area, fertilizers, population, livestock, air temperature etc.). This can be explained by both insufficient data for a full-scale analysis and by the complex relationships between the processes that cause the algal blooms. Further accumulation of novel data may allow a more detailed identification of the patterns of eutrophication throughout the country.

4.2. Causes and Effects of Algal Blooms

The massive development of algae in water bodies is caused by a complex of abiotic and biotic factors including elevated temperature, flow rate of the reservoir, the content of nutrients in the water and bottom sediments, the flow of contaminated wastewater, the removal of fertilizers from the fields, etc. [55]. The most important factors causing eutrophication of water bodies are considered to be the entry of phosphorus and nitrogen compounds [1]. Temperature is also considered as an important factor determining the growth rate of algae and, probably, the distribution of cyanobacterial toxins on the continental scale [56].

The role of global climate change in the eutrophication of reservoirs on a world scale has not yet been precisely determined. Satellite observations of 71 of the largest lakes in various parts of the world showed that in 68% of the lakes, the bloom intensity of algae has increased over the past 30 years. Nevertheless, a comparison of algal blooming trends with environmental factors such as temperature, rainfall, and fertilizer use did not show a significant correlation, except for the fact that in lakes not prone to warming, bloom activity decreased [6].

A significant number of scientific articles is devoted to the problem of eutrophication of water bodies in Russia and development of toxin-producing cyanobacteria [57]. Many of these articles are published in Russian and are not translated into English thus making it non-accessible by the international community. There are several examples of the complex studies of the eutrophication of water bodies in Russia.

An example of eutrophication due to industrial pollution sources is the blooming of the northern part of the Vygozersky reservoir in Karelia on the north of Russia due to the discharge of sewage from the Segezha industrial center. Several decades of observations of the reservoir (1950–2010) show that its trophic state directly depends on the operation of the plant. In the 1960s, the Segezha Pulp and Paper Mill was built on the shore of Northern Vygozero. The eutrophication process in the reservoir began soon after that. By 1980s the amount of chlorophyll *a* in the photic zone increased from 1.1 to 11.4 mg/m^3. The maximum emissions of phosphorus were recorded in 1976–1981, when the average anthropogenic load in the reservoir for the total phosphorus was 0.47 g/m^2 per year. Since 1982, as production decreased, the indicators of anthropogenic load of total phosphorus were gradually reduced, reaching 0.03 g/m^2 per year in recent years, which is only 10% of the natural load (0.31 g/m^2 year) [58].

In a number of towns, the wastewater treatment plants do not purify wastewater to the maximum permissible concentrations. For example, in the city of Orenburg, water with high nutrient contents flows directly into the Ural River located on the territory of two states: Russia and Kazakhstan. The efficiency of phosphate removal from urban wastewater is 66.5% and the output concentration of phosphates decreases from 2.89 to 0.97 mg/L, but the resulting concentration at the exit is still 4.85 times higher than the maximum permissible concentrations. The concentration of ammonium ions as a result of purification decreases from 37.56 to 1.95 mg/L and the purification efficiency is 94.8%, however, the final concentration of ammonium ions exceeds the maximum permissible concentrations by 3.9 times. The wastewater treatment facilities of Orenburg do not provide the treatment of effluents from nitrite ions and during treatment their concentration increases from 0.14 to 0.53 mg/L, which exceeds the maximum permissible concentrations by 6.6 times. These indicators show a gradual eutrophication of the Ural River [59].

Another example of the ongoing eutrophication is the deterioration of the water in Tsimlyansk reservoir located in the southern part of Russia. *Aphanizomenon flos-aquae*, *Microcystis aeruginosa*, *Microcystis wesenbergii*, *Microcystis viridis*, *Planktothrix agardhii*, *Pseudanabaena limnetica*, *Planktothrix rubescens*, *Oscillatoria limosa*, *Aphanizomenon gracile*, *Dolichospermum flos-aquae*, and others were detected in the samples [60]. The number of cyanobacterial cells in the samples in August 2013 reached 319 million cells/L. Moreover, five types of microcystin and anatoxin-a were identified [20]. According to media reports, the storm water drainage discharges into the Tsimlyansk reservoir through seven collectors, while only one collector is equipped with treatment facilities. The solving of this problem requires significant economic costs. The cost of new treatment facilities in the city of Volgodonsk and reconstruction of the storm water drainage system is estimated at 1.226 billion rubles (data for 2016) that is equal to one third of the city's budget expenditures per year [61].

The effects of algal blooms reported in the mass media are mostly related to social issues such as unwillingness or inability to swim in the reservoir, concerns about the possible presence of toxins in the drinking water, decrease in the tap water quality, or even the cessation of water supply to the population. The negative environmental consequences of eutrophication of water bodies are mostly associated with the death of fish or birds that is often mentioned in the article headings.

4.3. Public and Governmental Reaction to Algal Blooms in Russia

From the point of view of public reaction, water pollution is one of the most important environmental problems in Russia. According to the statistics of appeals to the Public Chamber of the Russian Federation in 2015, appeals regarding pollution of water bodies accounted for 59% of requests regarding the state of the environment [62].

The most acute public reaction to the problem of eutrophication was associated with the algal bloom in Lake Baikal in July 2016 [52]. It attracted the attention of the general public, the media, and the government to the problem of the deterioration of the ecological status of water bodies. As a result, in December 2016 in the appeal to the Federal Assembly of Russia the President of Russia set the task of preserving the ecosystems of Lake Baikal, the Volga reservoirs and Lake Teletskoye in the Altay Territory. In 2018, national projects were approved to preserve the ecosystems of the largest lakes and rivers in Russia, including Lake Baikal, Teletskoe, Ladoga, Onega and the Volga, Don, Ob, Yenisei, Amur, Ural, Pechora rivers [63].

The data collected and the analysis of scientific publications show that the problem of eutrophication in Russia is not limited only to the largest water bodies but also is widely represented in small reservoirs, which, therefore, were out of the focus of attention of state environmental projects. It should be noted that the identification and consideration of environmental problems in small reservoirs is currently quite a challenge and requires the development of new approaches [64].

4.4. Mass Media Representation of Algal Blooms in Russia

We used the analysis of media reports as one of the possible methods of collecting information on outbreaks of algae. Using news aggregators allows to quickly receive information from remote regions of Russia, expanding the geographical coverage of the study of the problem of eutrophication. Media analysis is also important because of their role in shaping the overall environmental policy agenda, although they do not have a formal role in this process, such as experts, lawmakers, law enforcement officials, and government agencies do. Earlier, a similar role of the press was noted in the analysis of media coverage of the Baltic Sea eutrophication process [65,66].

In our opinion, the method of collection of information about algal blooms using mass media analysis has a number of strengths and weaknesses. The advantages of the method include: (1) the economic efficiency of data collection achieved through the use of news aggregators, (2) a wide geographical coverage, (3) a large amount of information about the public's reaction to algal blooms and their socio-economic consequences. The disadvantages of the method include: (1) the dependence on the severity of perception of the problem in a particular region, (2) the dependence of the situation assessment on the availability of qualified specialists, (3) a low attention to long-term reasons for the eutrophication of water bodies as opposed to a high level of attention to external signs of eutrophication.

We think that the data obtained during the analysis of the media should be treated with some caution, but these data are at least suitable for preliminary conclusions about the geographical distribution of algal outbreaks and the reaction of society to them. A deeper analysis of the situation, as well as identifying the causes of algal blooms, clearly requires the involvement of qualified specialists in the field. The fact that in 70% of messages the dominant types of phototrophic microorganisms causing blooming were indicated may imply that in many cases a preliminary expert analysis had been carried out.

4.5. Comparison of the Mass-Media and Scientific Reports

We suppose that a direct comparison of the results obtained through analysis of the media and scientific publications is inefficient due to the very different sample sizes (60 cases described in the media and 11 cases described in the scientific literature). Nevertheless, some preliminary conclusions can be made based on the available data.

Firstly, the data obtained indicate the interest of mass media in the scientific expertise of algal blooms. The indication of the dominant types of microorganisms in 70% of cases described in the media can be an indirect confirmation. It is logical to assume that the information on the microorganism that dominates during the bloom can be obtained by journalists only from experts with relevant technical capacities and expertise. Therefore, the presence of information on the species composition of microorganisms in the media indicates a request for information from scientists.

Secondly, the public, enterprises, local authorities, and mass media are a source of timely information on algal outbreaks for scientists. Three scientific articles contain direct references to appeals from enterprises and local authorities to scientists [44,47,50]. Besides, our own experience of work on analysis of bloom samples from Lake Baikal [54] points out the role of mass media and the public.

The above-mentioned examples of interaction between local people, mass media, businesses, local authorities, and academics show the importance of collaboration and information sharing. The scientific expertise is crucial for the population, authorities, and business to identify the problem correctly and find the ways to solve it, as well as to understand the deeper consequences of algal blooms, such as the emergence of toxic species of cyanobacteria and microalgae. On the other hand, the information received from the public, mass media, authorities, and business are important for scientists as an early warning about the algal blooms. The use of media data analysis is especially promising within the framework of an actively developing area of integrated monitoring where data are collected from citizens (citizen science), scientific research, and state monitoring. Such projects are most effective in analyzing small scale pollution, such as the iWitness Pollution project addressing oil pollution problems [64,67]. A prerequisite for the success of such projects is the central role of the scientific community in research planning [68].

5. Conclusions

The main conclusion obtained from the analysis of media reports on algal outbreaks is that they occur in all major climate zones and all federal districts of Russia. The largest number of reports of the algal blooms comes from the south of the European part of the Russian Federation. This can be explained by a combination of natural and anthropogenic factors (warm climate, the supply of nutrients from well-developed agriculture and tourism, and the low flow rate of some rivers and water bodies). However, we did not find significant correlations between statistics on factors causing eutrophication and the number of algal outbreaks in the regions. The algal blooms attract considerable public attention in Russia, which makes the projects in the integrated monitoring of the ecological status of water bodies with public involvement very promising. The success of such projects would depend on the active participation of the scientific community in them.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4441/12/1/285/s1, Table S1: Statistical and environmental data on Russian regions, Table S2: Mean values of statistical data in Federal Districts in 2016–2018.

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