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Abstract: Cyanobacterial blooms constitute a global environmental concern, with sometimes serious implications for human and animal health. Consequently, they represent a major problem in the management of water and aquatic ecosystems. The design of good quality control and management programs is therefore imperative and, for this, a good understanding of the state of the art becomes essential. In Spain, information related to freshwater cyanobacteria is somewhat scattered. Thus, the main objective of this work is to gather all the available information related to cyanobacteria in Spanish artificial water bodies (reservoirs), with special attention to episodes of massive proliferation and probable toxic events. Data for this review were obtained from scientific papers, technical reports, and from the websites of the different Spanish basin organizations. From the review carried out, it is relevant that: cyanobacteria species have been recorded in 252 of the 988 existing reservoirs and blooms in 91 of them (most of them destined for water supply), potentially toxic cyanobacteria are widespread, and that occurrence of blooms has increased recently. The latter could be attributed to a spread monitoring effort. Nevertheless, the effect of the increasing eutrophication and climate change should not be underestimated. In addition to the data compilation, the relation between the cyanobacteria recorded in the Spanish water reservoirs and the geological area where the reservoirs are located has been analyzed.

Keywords: CyanoHABs; algal blooms; water-reservoir; monitoring; eutrophication; blooms

1. Introduction

The proliferation of planktonic cyanobacteria in lakes and water reservoirs is related to eutrophication processes. Blooms can modify the chemical conditions of the water with the consequent impact on the survival of other aquatic organisms [1–3]. Additionally, they are generally associated with the presence of cyanotoxins [4–8]. Numerous cyanobacterial species can produce toxins [9–11], including some of the most potent toxins known [8]. It is estimated that 50% (25% to 75%) of cyanobacterial blooms are toxic and generally 75% of the cyanobacteria that appear in a bloom can produce one or more types of toxins. Thus, CyanoHABs (cyanobacterial harmful algal blooms) constitute a serious environmental problem, with implications in human and animal health [3,12–16]. Numerous known cases of lethal poisoning of animals and even of human populations occurred worldwide [11,17], but is important to consider that the damage produced by toxins varies depending on the affected organism. For example, mammals are mainly affected by neurotoxic toxins, which disturb the transmission of nerve impulses and can cause death by respiratory arrest, or by hepatotoxins, which produce changes in cell structure, leading to hepatocellular necrosis, extensive hemorrhagic necrosis, and sinusoidal disruption. In humans, cyanotoxins can produce hepatic damage and can lead to death by intrahepatic hemorrhage and hypovolemic shock [18]. In non-lethal doses, these toxins have been attributed a
tumor-promoting action, and epidemiological studies suggest an increased incidence of hepatocellular carcinoma [19]. And in fish, there is less information on the pathology, affecting not only the liver, but also other organs, such as kidney, heart, gills, skin, marrow, and blood [12]. Moreover, and in addition to the health implications, cyanobacterial blooms have an economic impact with increasing costs of drinking-water treatments and the decrease of recreational water values [3,11,20]. Therefore, they must be considered in the management of water and aquatic ecosystems.

In temperate regions, cyanobacterial blooms usually occur in summer, when temperature and light intensity are high and nutrient renewal and water column conditions stable [21–24]. Some environmental factors can determine an increased abundance of potentially toxic cyanobacteria during a bloom: high phosphorus and nitrogen concentration, low N:P ratio, high residence time and low water renovation rate, low turbulence, high light intensity, high temperature, the increase of dissolved organic matter, iron and trace metals, and low planktophages rates [10]. The frequency and intensity of blooms have risen recently worldwide. This increase has been attributed to anthropogenic changes, primarily the over-enrichment with nutrients and river regulation [25,26]. The possible effects of climate change on water eutrophication, and consequently the increased risk of potentially toxic cyanobacterial blooms, have also been noted [26,27]. Because of this increase and its health and management implications, blooms have drawn the attention of environment agencies, water authorities, and human and animal health organizations with the consequent development of monitoring programs and the publication of numerous technical reports, e.g., [28–37]. Moreover, the Water Framework Directive (WFD) (Directive 000/60/EC [1]) specifies that the ecological status based on phytoplankton should be defined by measuring the biomass, composition, and blooms, especially cyanobacterial blooms. In addition, new methodological approaches to monitor, control, or eliminate cyanobacteria from the environment are being developed [38,39].

In Spain, most lentic systems are reservoirs, with different degrees of eutrophication, which favors the proliferation of cyanobacteria. Despite this situation and the growing interest, the available official information is scattered, and cyanobacterial bloom episodes have gone unnoticed frequently in Spanish waters. This could be influenced by the complexity of the Spanish administration and water authorities (there are 19 “river basin districts” according to the RD 125/2007 and RD 29/2011). Regarding the scientific knowledge, in the last years, several studies have been published; nevertheless, the available scientific information is also somewhat patchy. Some works are focused on phytoplankton occurrence in reservoirs scattered all over the country [40,41], others on reservoirs of specific regions [42–48], or on a unique reservoir [49–61]. Furthermore, none of the more thorough studies [58,62,63] are focused over the entire territory.

Since the design of good monitoring and management programs depends on a good understanding of the matter (information on past cyanobacterial blooms, the existing species, their relationships with environmental conditions, etc.), the main objective of the present work is to gather in a single document the available information (from scientific papers and technical reports) on the cyanobacteria and bloom records in Spanish reservoirs, in order to provide a basis to picture the background of the situation. In addition, some circumstances related to the occurrence on blooms are also discussed.

2. Materials and Methods

A bibliometric method was used to analyze the global SCI literature on cyanobacterial blooms in Spanish reservoirs from WOS database (search terms: cyanobacteria, blooms in Spanish reservoirs, Spanish cyanobacterial blooms, harmful algal blooms, HABs, CyanoHABs, monitoring algae blooms). In addition, information on the websites of all basin organizations and technical reports have been consulted. Data covers a range from 1981 to 2017. Specific information of the reservoirs with cyanobacterial records have also been collected. The geological data for every reservoir was obtained from IGME (Instituto Geológico y Minero de España—Geological and Mining Institute of Spain).
The most relevant information has been compiled in tables, extended versions of these included in the manuscript can be consulted as Supplementary Material. In addition to the review, the relations between the cyanobacterial records and the geology where the reservoirs are located were analyzed. To do this, a similarity dendrogram was performed in the statistical package SYSTAT 13.0 software using the Ward method with Euclidean distance. Since in many cases, the information available on the presence of cyanobacteria includes dubious identifications at a specific level or, only identifications at genus level, to maintain consistency we used the cyanobacterial genera for the analysis.

3. Results and Discussion

3.1. Occurrence of Cyanobacteria and Blooms in Spanish Reservoirs

Based on the review carried out, cyanobacteria have been recorded in 252 of the 988 existing reservoirs (Figure 1, Supplementary Material Table S1) with blooms documented in 91 of them. Thus, blooms have been detected in 36% of the existing reservoirs. This is consistent with Quesada et al. [58] who estimated that around 40% of the Spanish reservoirs are susceptible to proliferation episodes. The absence of record in over 600 reservoirs could be related to the potential bias suggested in the introduction, regarding the fact that the available information is scattered, and with the fact that until the last five years there were no general surveillance and warning campaigns the formation of blooms.

Figure 1. Map of Spain showing the reservoirs with records of cyanobacteria. Numbers correspond to reservoirs (see Supplementary Material—Table S1). Green dots indicate reservoirs with cyanobacteria but without registered blooms. Red dots indicate reservoirs with cyanobacterial blooms registered at least once. River Basin Districts (RBD) indicated and represented by background colors.
Among the 19 Spanish river basin districts, Balearic Islands and Galicia-Costa are those with the most reservoirs with cyanobacterial records (100% and 66.67%, respectively). Galicia-Costa is the river basin district with the highest number of reservoirs in which blooms have been recorded (37%, Table 1).

Table 1. Reservoirs with cyanobacteria and bloom records regarding to the River Basin District (RBD) where they are located (AMB: Andalucía Mediterranea; BCB: Basque Country; BI: Balearic Islands; C: Cantabrian; CIB: Catalonia Interna; D: Duero; E: Ebro; G-B: Guadalete-Barbate; G-C: Galicia-Costa; Gd: Guadiana; J: Júcar; M-S: Minho-Sil; S: Segura; T: Tajo; TOP: Tinto, Odiel Piedras).

| RBD     | Reservoirs in the RBD | With Cyanobacteria | %     | With Registered Blooms | %     |
|---------|-----------------------|--------------------|-------|------------------------|-------|
| G-C     | 27                    | 18                 | 66.67 | 10                     | 37.04 |
| M-S     | 60                    | 11                 | 18.33 | 10                     | 16.67 |
| C       | 46                    | 7                  | 15.22 | 1                      | 2.17  |
| BCB     | 14                    | 4                  | 28.57 | 0                      | 0.00  |
| D       | 80                    | 25                 | 31.25 | 6                      | 7.50  |
| E       | 175                   | 36                 | 20.57 | 2                      | 1.14  |
| CIB     | 13                    | 4                  | 30.77 | 2                      | 15.38 |
| T       | 217                   | 69                 | 31.8  | 41                     | 18.89 |
| Gd      | 92                    | 24                 | 26.09 | 11                     | 11.96 |
| J       | 46                    | 15                 | 32.61 | 3                      | 6.52  |
| TOP     | 33                    | 6                  | 18.18 | 0                      | 0.00  |
| Gq      | 96                    | 5                  | 5.21  | 1                      | 1.04  |
| S       | 34                    | 6                  | 17.65 | 1                      | 2.94  |
| G-B     | 15                    | 5                  | 33.33 | 1                      | 6.67  |
| AMB     | 38                    | 15                 | 39.47 | 2                      | 2.26  |
| BI      | 2                     | 2                  | 100.00| 0                      | 0.00  |
| Total   | 988                   | 252                | 91    | 257                    |       |

Something worth noting is that 139 of the 252 reservoirs with cyanobacteria are water supply reservoirs (Table 2) and most of the blooms have occurred in this type of water body (Table 2). This higher incidence could be linked to a greater monitoring effort, in order to ensure health safety, which is indispensable in reservoirs intended for water supply for human use. Nonetheless, it is undoubtedly a fact that highlights the health hazards associated with cyanobacterial blooms and the management implications.

Table 2. Reservoirs with cyanobacteria and bloom records regarding to the main water use of the reservoirs (Aqu: Aquaculture; Fd: Flood defence; Fish: Fishing; Hyd: Hydroelectric; Ind: Industrial; Irr: Irrigation; Liv: Livestock sector; Rec: Recreational; Sto: Storage; Wd: Water derivation; Ws: Water supply).

| Water Use | Total Reservoirs | Reservoirs with Cyanobacteria | Reservoirs with Registered Blooms | Number of Blooms Registered |
|-----------|------------------|-------------------------------|----------------------------------|----------------------------|
| Aqu       | 2                | 0                             | 0                                | 0                          |
| Fd        | 36               | 6                             | 1                                | 1                          |
| Fish      | 4                | 0                             | 0                                | 0                          |
| Hyd       | 280              | 58                            | 23                               | 61                         |
| Ind       | 32               | 9                             | 4                                | 11                         |
| Irr       | 193              | 33                            | 15                               | 41                         |
| Liv       | 4                | 0                             | 0                                | 0                          |
| Rec       | 18               | 1                             | 1                                | 2                          |
| Sto       | 14               | 6                             | 2                                | 8                          |
| Wd        | 17               | 0                             | 0                                | 0                          |
| Ws        | 388              | 139                           | 45                               | 133                        |
| Total     | 988              | 252                           | 91                               | 257                        |
3.2. Species of Cyanobacteria in Spanish Reservoirs

According to the available information, 126 different species of cyanobacteria, belonging to 38 genera, have been identified in the Spanish reservoirs (Supplementary Table S2 for references). In several of the consulted works, identifications remained at the genus level (as Genus sp.; indicated here as spp.). A detailed list with the identified taxa and the reservoirs in which they were cited is available in the Supplementary Material (Table S2).

Of the 38 genera, 11 have been recorded in more than 20% of the reservoirs, while the remaining have a much narrower distribution range (Table 3), with species recorded in only one reservoir. Several available studies state that *Microcystis* and *Microcystis aeruginosa* are the most common genus and species in Spanish waters, e.g., [2,58,64–71]. However, from the review carried out for this work, it is found that the most common genus in the Spanish reservoirs is *Anabaena* (60.71% of the 252 reservoirs), followed by *Microcystis* (57.14%), and *Aphanizomenon* (50.00%) (Table 3). Of the identified species, most of them have a low distribution range, being present in less than 10% of the reservoirs with record of cyanobacteria (see Table S2). The most frequent species (distribution range > 10%) (Table 4) are species of the genus *Anabaena* (*Anabaena* spp.) (38.49%), *Microcystis aeruginosa* (34.13%), *Woronichinia naegeliana* (32.54%), and *Aphanizomenon flos-aquae* (30.16%).

Table 3. Distribution range (% of the reservoirs with cyanobacteria records in which each genus was recorded) of the identified genera of cyanobacteria in the Spanish reservoirs.

| Genus                  | Distribution Range |
|------------------------|--------------------|
| Anabaena               | 60.71              |
| Microcystis            | 57.14              |
| Aphanizomenon          | 50.00              |
| Aphanocapsa            | 40.08              |
| Merismopedia           | 38.89              |
| Pseudanabaena          | 37.30              |
| Woronichinia           | 35.32              |
| Oscillatoria           | 30.95              |
| Chroococcus            | 26.98              |
| Aphanotoce             | 22.22              |
| Planktothrix           | 21.43              |
| Coelosphaerium         | 9.92               |
| Anabaenopsis           | 8.73               |
| Cylindrospermopsis     | 7.94               |
| Phormidium             | 7.54               |
| Limnothrix             | 7.54               |
| Synechococcus          | 7.54               |
| Gelerinema             | 7.14               |
| Snowella               | 5.95               |
| Planktoendyghya        | 5.56               |
| Spirulina              | 5.16               |
| Raphidiopsis           | 4.37               |
| Synechocystis          | 4.37               |
| Romeria                | 3.97               |
| Lyngbya                | 2.78               |
| Nostoc                 | 2.38               |
| Gomphosphaeria         | 2.38               |
| Cyanogranis            | 1.98               |
| Cylindrospermum        | 1.59               |
| Radiocystis            | 1.59               |
| Jaeginema              | 1.59               |
| Tolypothrix            | 0.79               |
| Arthrospra             | 0.40               |
| Dermocarpella          | 0.40               |
| Gloecapsa              | 0.40               |
| Schizothrix            | 0.40               |
| Chamaesiphon           | 0.40               |
| Coelomorin             | 0.40               |
Table 4. Species of cyanobacteria with a distribution range of over 10% (Complete data in Supplementary Material—Table S2) (Distribution range: % of the reservoirs with cyanobacteria records in which each taxon was recorded).

| Species                     | Distribution Range |
|-----------------------------|--------------------|
| Anabaena spp.               | 38.49              |
| Microcystis aeruginosa      | 34.13              |
| Woronichinia naegeliana     | 32.54              |
| Aphanizomenon flos-aquae    | 30.16              |
| Microcystis spp.            | 26.19              |
| Pseudanabaena spp.          | 23.41              |
| M. tenuissima               | 23.41              |
| Aphanizomenon gracile       | 18.25              |
| Anabaena flos-aquae         | 17.46              |
| Microcystis flos-aquae      | 17.46              |
| Aphanizomenon spp.          | 17.06              |
| Aphanocapsa spp.            | 16.67              |
| Oscillatoria spp.           | 16.27              |
| Oscillatoria limnetica      | 15.87              |
| Planktothrix agarthii       | 15.08              |
| Aphanocapsa holsatica       | 14.29              |
| Anabaena spiroides          | 13.89              |
| Aphanocapsa incerta         | 13.49              |
| Anabaena circinalis         | 13.10              |
| Oscillatoria agarthii       | 13.10              |
| Anabaena planctonica        | 12.70              |
| Merismopedia spp.           | 12.70              |
| Chroococcus spp.            | 12.30              |

In addition to native species, 2 exotic cyanobacteria have been recorded: *Aphanizomenon ovalisporum*, in 8 reservoirs, and *Cylindrospermopsis raciborskii*, in 18. The first one comes from tropical and subtropical regions, although the recent appearance in temperate latitudes is considered as an expansion of its natural distribution [72] and the second is established in the Spanish region according to De Hoyos et al., 2004. The potential impact [73] of these and other possible exotic cyanobacteria has not been studied in Spanish waters. Nevertheless, the potential production of highly-toxic cylindrospermopsin by *C. raciborskii* has been assessed; therefore, this can be applied to Spanish waters.

It is relevant that there is a different degree of taxonomic expertise in the consulted sources, with identifications at different taxonomical levels even in the same study, and sometimes ambiguous identifications. This could constitute another bias in the knowledge of the background of cyanobacterial occurrence in Spanish waters. In this paper, the identifications have been kept as they appear in the consulted works, since we consider that the scope was the collection of data and not the taxonomic or nomenclatural arrangement. Being aware that, for example, synonymous or current unaccepted names could appear in the main text and the Supplementary Material (e.g., the use of *Anabaena* instead of *Dolichospermum*; [74]).

3.3. Toxic Cyanobacteria and Blooms in Spanish Reservoirs

According to the available data, 257 blooms occurred in 91 reservoirs between 1981 and 2017. The dominant species in blooms varies between reservoirs and even within the same reservoir in different episodes (Supplementary Material—Table S3).

The most frequently dominant species in blooms (Table 5) are: *Microcystis aeruginosa* (17.90%), *Aphanizomenon flos-aquae* (12.84%), and *Woronichinia naegeliana* (9.34%). These species have the potential to produce cyanotoxins; moreover, microcystins are considered the main pollutants in freshwater in terms of risk for human health [14]. Therefore, blooms produced by these species are of great concern.
It is assumed that, in Europe, cyanobacterial blooms are mainly dominant by species of genera Microcystis, Planktothrix, Anabaena, and Aphanizomenon [15]. Agha [70] stated that Microcystis, Planktothrix, Anabaena, and Aphanizomenon are the most frequent genera in the Spanish waters. Our data compilation agrees with both works in the dominance of Microcystis and Aphanizomenon. However, it shows a lower frequency of appearance of Planktothrix (2.72% for P. agardhii and 3.11% for P. rubescens) and Anabaena (between 0.39% for A. sphaerica and 2.72% for A. planctonica) (Table 5).

*Microcystis aeruginosa* is the most globally common source of toxic blooms and it also has a higher incidence in Spain (17.9%) (Table 5), but it is not the only potentially toxic species recorded in Spanish reservoirs. Potential producers of microcystins (e.g., *Microcystis* spp., *M. aeruginosa*, *M. smithii*, *M. flos-aquae*, *M. novaceckii*, *M. wesenbergii*, *Anabaena* spp., *A. flos-aquae* and *P. agardhii*), cylindrospermopsin (e.g., *Aphanocapsa ovalisporum* and *Cylindrospermum raciborskii*) and anatoxin-a (e.g., *Anabaena circinalis*, *A. flos-aquae*, *A. planctonica*, *Aphanizomenon flos-aquae*, *Cylindrospermum* spp., *Oscillatoria* spp., *Planktothrix* rubescens, and *Raphidiopsis mediterranea*) have also been documented [39].

Data on cyanobacteria in Spanish reservoirs seem to indicate that blooms have been increased in recent years (Figure 2). This can be associated with many causes still as the
increasing eutrophication, river regulation, or the gradual temperature increase as consequence of climate change [15,27,36]. The increasing monitoring effort, especially in water supply reservoirs, should not be dismissed. In addition, studies on the toxicity of these blooms, including measurements on the dissolved cyanotoxins in water, should be implemented. While increased monitoring efforts are leading to more records of the presence of these organisms and the formation of blooms, progress is still needed in the implementation of standardized measures to understand their consequences and facilitate management.

For this work, we considered a bloom an episode where the recorded cyanobacterial abundance was higher than 20,000 cells per milliliter, which corresponds to 10 μg of chlorophyll “a” per liter.

3.4. Cyanobacteria and Geology

On a broad geographic scale, it has been demonstrated that phytoplankton, in Spanish reservoirs, is mainly influenced by two environmental factors: the mineral water contents, depending on bedrock geology and climate [40,75–78], and the trophic state of the water body (see references in [78]).

During the analysis of the information, it emerged a derived objective: investigating the relation between the cyanobacteria recorded in the Spanish water reservoirs and the geological area where the reservoirs are located. Reservoirs with cyanobacterial occurrence (252 reservoirs) belong to 21 different specific geological areas that can be distinguished (Figure 3).

- Siliceous zones (types I: Gneiss, schist, marble, and vulcanite; J: Granitoid; O: Peridotite; P: Quartzite, slate, sandstone, limestone, and vulcanite; S: Schist and limestone; and U: Slate, schist, and paragneiss) and calcareous zones (types A: Calcareous turbidite; B: Conglomerate, sandstone, clay, and limestone. Evaporite; C: Conglomerate, sandstone, clay, limestone, and evaporite. Basic vulcanite; D: Conglomerate, sandstone, limestone, gypsum, and versicolor clay; E: Conglomerate, sandstone, lutite, limestone, and gypsum; F: Conglomerate, sandstone, lutite, limestone, loam, and gypsum; G: Conglomerate, sandstone, slate, limestone, and vulcanite. Coal; H: Dolomite, limestone, and calcarenite; K: Limestone; L: Limestone and gypsum; M: Limestone, dolomite, and loam. Conglomerate and sandstone; N: Loam and limestone; Q: Sandstone and limestone; R: Sandstone, slate, and limestone; T: Schist, grey wake, paragneiss, and basic vulcanite) (Figure 3). Consequently, 118 of the 252 reservoirs with cyanobacterial records (46.83%) are in siliceous areas and 134 (53.17%) in calcareous zones. Of the 91 reservoirs with reported
blooms, 51.69% are in siliceous zones, whereas only the 22.39% belong to calcareous areas (Supplementary Material—Tables S1 and S3). These results are consistent with those reported by De Hoyos et al. (2004): cyanobacterial blooms in the Iberian Peninsula are more frequent in reservoirs located to the west, with less soluble rocks (siliceous zone), than in those located in the east, where rocks are more soluble.

Figure 3. Percentage of reservoirs with cyanobacteria records according to the geology area type where they are located (Only types I, J, O, P, S, and U correspond to siliceous areas (A: Calcareous turbidite; B: Conglomerate, sandstone, clay, and limestone. Evaporite; C: Conglomerate, sandstone, clay, limestone, and evaporite. Basic vulcanite; D: Conglomerate, sandstone, limestone, gypsum, and versicolor clay; E: Conglomerate, sandstone, lutite, limestone, and gypsum; F: Conglomerate, sandstone, lutite, limestone, loam, and gypsum; G: Conglomerate, sandstone, slate, limestone, and vulcanite. Coal; H: Dolomite, limestone, and calcarenite; I: Gneiss, schist, marble, and vulcanite; J: Granitoid; K: Limestone; L: Limestone and gypsum; M: Limestone, dolomite, and loam. Conglomerate and sandstone; N: Loam and limestone; O: Peridotite; P: Quartzite, slate, sandstone, limestone, and vulcanite; Q: Sandstone and limestone; R: Sandstone, slate, and limestone; S: Schist and limestone; T: Schist, grey wake, paragneiss, and basic vulcanite; U: Slate, schist, and paragneiss).

Therefore, to determine if the blooms records were related or have a higher incidence in function on the geology of the area (siliceous or calcareous) where the reservoirs were located, a similarity dendrogram was performed. The dendrogram (Figure 4) shows two main groups, one group with the genera related with reservoirs located on areas with granitoid (siliceous) materials (Microcystis, Woronichinia, Aphanizomenon, Anabaena, Merismopedia, Aphanocapsa, Chroococcus, Pseudanabaena, and Oscillatoria), and a second group in which all the remaining genera are bounded together. Being the genera linked to the granitoid areas, the most frequent ones in blooms (>25%) (Table 4).
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Figure 4. Similarity dendrogram based on the relation between cyanobacterial genera and the geological area where reservoirs in which they were recorded are located (A: Calcareous turbidite; B: Conglomerate, sandstone, clay, and limestone. Evaporite; C: Conglomerate, sandstone, clay, limestone, and evaporite. Basic vulcanite; D: Conglomerate, sandstone, limestone, gypsum, and versicolor clay; E: Conglomerate, sandstone, lutite, limestone, and gypsum; F: Conglomerate, sandstone, lutite, limestone, loam, and gypsum; G: Conglomerate, sandstone, slate, limestone, and vulcanite. Coal; H: Dolomite, limestone, and calcarenite; I: Gneiss, schist, marble, and vulcanite; J: Granitoid; K: Limestone; L: Limestone and gypsum; M: Limestone, dolomite, and loam. Conglomerate and sandstone; N: Loam and limestone; O: Peridotite; P: Quartzite, slate, sandstone, limestone, and vulcanite; Q: Sandstone and limestone; R: Sandstone, slate, and limestone; S: Schist and limestone; T: Schist, grey wake, paragneiss, and basic vulcanite; U: Slate, schist, and paragneiss).

4. Conclusions

Once the data was compiled and analyzed, it became evident that the available information for each reservoir is variable and scattered. Standardizing the information is an important target in order to be able to make comparisons. Uniform information is also helpful when it comes to the development of monitoring and control programs.

Species identification and nomenclature in some of the consulted works (mainly technical reports) is sometimes not precise. Greater effort in this sense would be desirable. Cyanobacterial species with a greatest distribution in Spanish reservoirs are Anabaena spp. (38.49%), Microcystis aeruginosa (34.13%), Woronichinia naegeliana (32.54%), and Aphantzomenon flos-aquae (30.16%). Blooms have been dominated most frequently by Microcystis aeruginosa (17.90%), Aphantzomenon flos-aquae (12.84%), Microcystis spp. (11.28%), and Woronichinia naegeliana (9.34%). All of them can potentially produce cyanotoxins, so their proliferation is of great concern.
Even though a slightly higher percentage of cyanobacterial records were made in calcareous areas (53.17% against 46.83% in siliceous areas), blooms have been recorded mainly in siliceous areas.

It is known that blooms have sometimes gone unnoticed, so the number of these episodes in Spanish reservoirs could be considered higher. The increase of bloom records during the last decade may be due to an improvement in the monitoring effort. Nevertheless, the effect of anthropogenic actions and climate change cannot be ruled out.

An increased monitoring efforts as well as standardization of sampling and analysis are desirable to mitigate the potential adverse effects of blooms, especially the toxic or potentially toxic ones.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/hydrobiology1010009/s1, Table S1: Characterization of the 252 Spanish reservoirs with cyanobacteria records, Table S2: Cyanobacteria in Spanish reservoirs and their distribution range (% of reservoirs of species with cyanobacterial records in which the genera/species have appeared), Table S3: Dominant species in each recorded bloom in Spanish reservoirs. Refs. [1,22,23,25,28–33,39,42–45,47,50–52,54–62,64,68,79–89].

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