Summary of the work performed and presented at the ZOOM ALGA meeting on November 28th, 2024

09:00	Starting	
09:05	Stéphan JACQUET	Short introduction
09:10	Frédéric SOULIGNAC *et al*.	A work on modelisation
09:20	Orlane ANNEVILLE *et al*.	Data analysis of chla peak
09:30	Orlane ANNEVILLE *et al*.	Side project : Modelisation around chla peak
09:40	Stéphan JACQUET *et al*.	Side project : VERTICYA (post-doc work)
09:50	Céline CASENAVE *et al*.	Side project : CYANOLEM (PhD work of AM)
10:00	Questions - Discussion part 1	
10:20	Nicolas TROMAS *et al*.	About benthic cyanobacteria
10:30	Mathilde DUGENNE *et al*.	Phytopk image analysis
10:40	Anna CARRATALA *et al*.	Gene and toxins
10:50	Bastiaan IBELINGS *et al*.	Side project: quagga
11:00	Laurene TO LAN GLASS HALER *et al*.	Side project: The LemanScope
11:10	Questions - Discussion part 2	
11:30	Frédéric SOULIGNAC *et al*.	Overview of the bibliography
11:40	Stéphan JACQUET *et al*.	Local documentation
11:50	Alexandre RICHARD *et al*.	Perception
12:10	Questions - Discussion part 3	
12:30	End of meeting	

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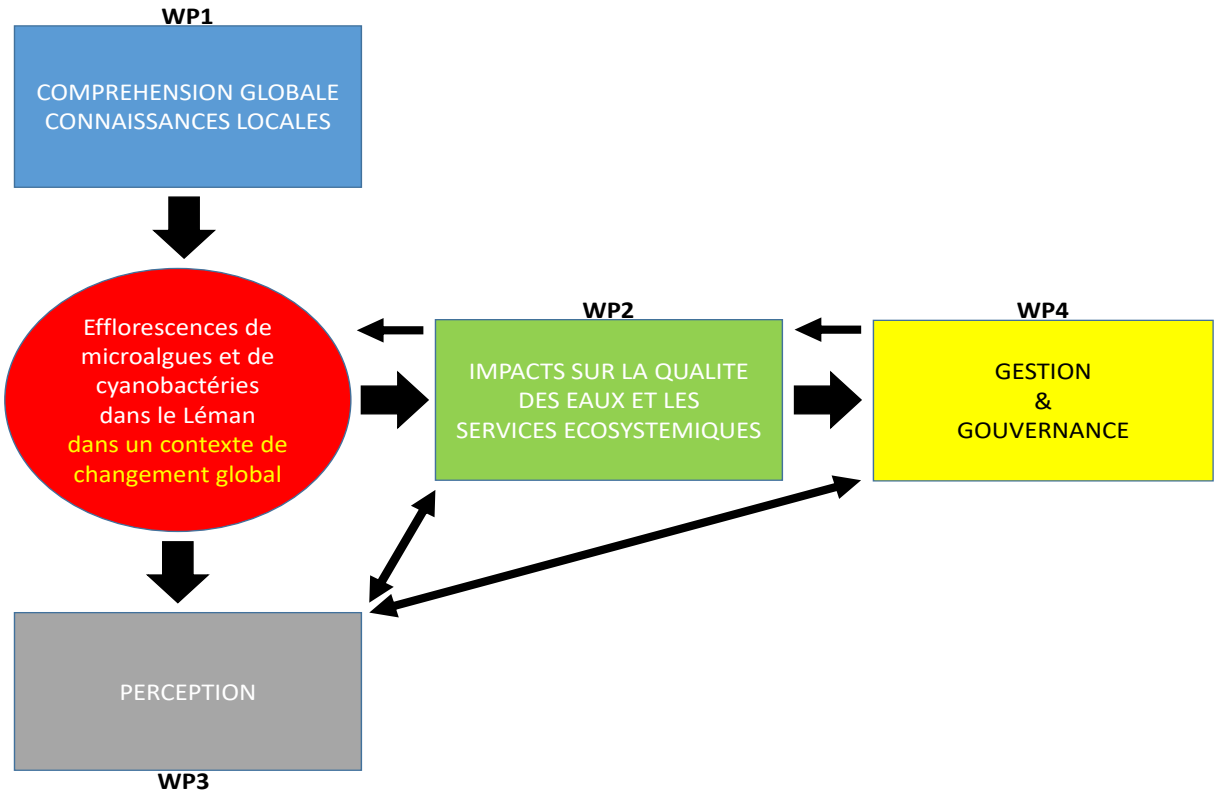
Work package structure ALGA



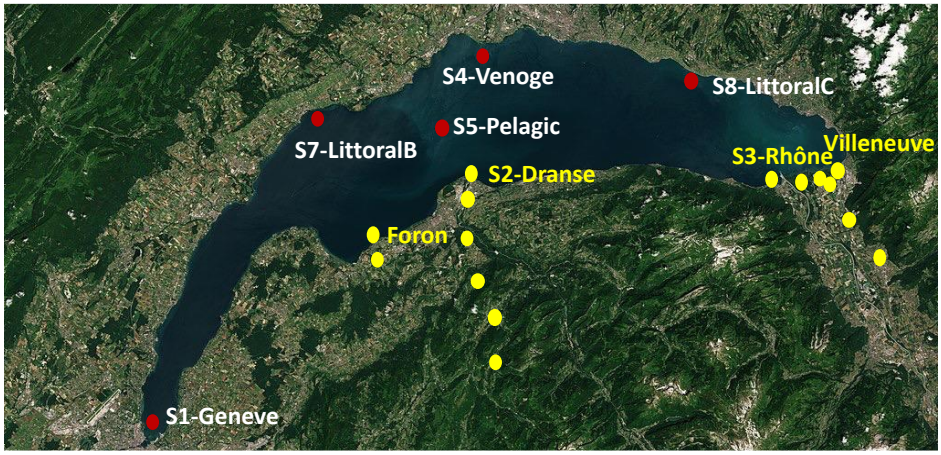
WP1 PROGRESS

WP1 – Benthic Cyanobacteria in and around Lake Geneva

Nicolas TROMAS, Valentin VASSELON, Bastiaan IBELINGS, Alexandre RICHARD, Stéphan JACQUET

As part of the work package 1, assessing the diversity, distribution and toxic potential of benthic cyanobacteria constitue a key issue. To date, much of the research has focused on understanding planktonic cyanobacteria blooms in order to develop predictive models and appropriate measures to reduce the frequency and intensity of these blooms. Over the past five years, there has been a notable increase in the number of studies focusing on toxic benthic cyanobacteria in rivers and lakes around the world. Anthropogenic activities and climate change favour the development of cyanobacterial populations and the frequency and persistence of harmful cyanobacterial blooms (cyanoHABs). An increasing number of observations of toxic benthic cyanobacteria have been made in or near the Rhônes-Alpes region, notably in the Ain and Lake Neuchatel. Several groups of planktonic cyanobacteria are regularly found in Lake Geneva, including *Planktothrix rubescens*, *Pseudoanabaena* and *Aphanizomenon*. These various cyanobacterial genera can be toxic and are monitored by the OLA observatory and Explore. The presence of benthic cyanobacteria, in particular *Tychomena*, has also been observed. However, to date there is no information on the distribution of these benthic mats of cyanobacteria in Lake Geneva. Furthermore, the level of risk posed by these cyanobacteria remains unknown, which prevents appropriate risk management. To our knowledge, the population structure of benthic cyanobacteria in Lake Geneva and its tributaries is still unknown. It is therefore important to characterise the population of these benthic cyanobacteria and gain a better understanding of the biotic and abiotic factors that could influence them. Furthermore, it is essential to ascertain whether these organisms are capable of producing cyanotoxins. The objective of this study is to contribute to our understanding of the ecological dynamics of potentially toxic benthic cyanobacteria in Lake Geneva and the surrounding streams.

During the summer of 2024, we conducted a sampling snapshot of several water systems along a transect (Foron, Dranse, Rhône and Eau froide). *Microcoleus anatoxicus* was identified by our colleagues in Neuchâtel (Diego Gonzales and Pilar Junier) after the death of a dog in Villeneuve, near the 'Eau froide' stream. This genus of benthic cyanobacteria is known to produce a neurotoxin called anatoxin. During fall 2024, we used a long-reads strategy (Nanopore) to sequence the gene encoding the entire 16S rRNA. We already identified potentially toxic genera including *Tychonema* and *Leptolyngbya* at several sites in Villeneuve and Foron. Other cyanobacteria, including *Microcystis* at the Villeneuve beach and harbour, were also found in cyanobacterial biofilms.

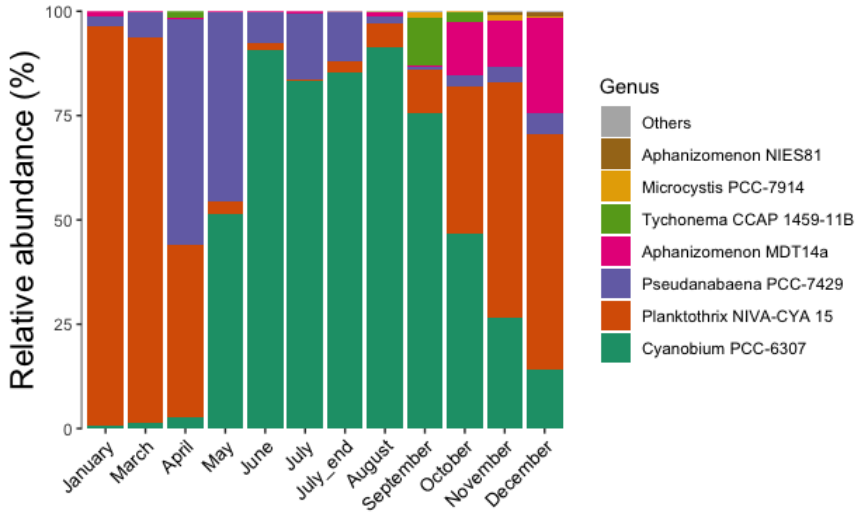


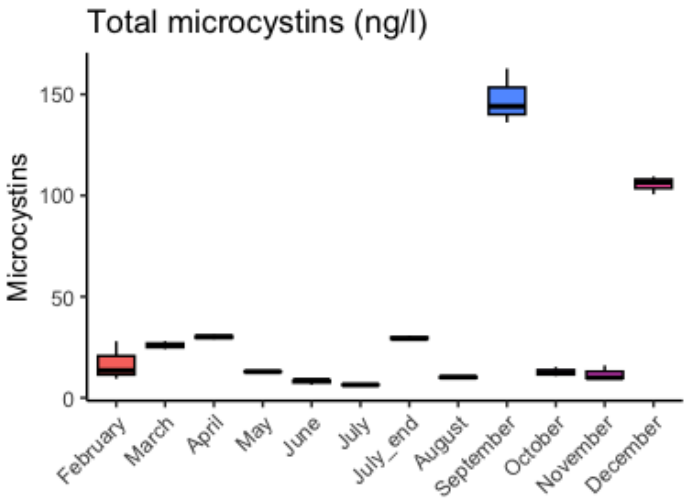
Sampling snapshot performed during summer 2024. Sites that have been sampled are represented in yellow.

WP1 -Toxic Cyanobacteria in Lake Geneva

Anna CARRATALÀ and Bastiaan IBELINGS

Within the context of work package 1, during the first year of ALGA we focused on understanding the dynamics of cyanobacteria populations and their role in microcystin production in Lake Geneva. To do this, we conducted a restrospective analysis of genetic data collected in 2020 from the LéXPLORE platform (Pully, Canton de Vaud). Using qPCR, the abundance of the *mcyA* gene, associated with microcystin synthesis, was found to closely mirror the total cyanobacteria levels in the lake. Sequencing of 16S rRNA revealed a seasonal pattern, with the genus *Planktothrix* dominating from November to April, and the picocyanobacterium *Cyanobium* prevailing from May to September. Interestingly, microcystin peaks were detected in the deep chlorophyll maximum (DCM) biomass during September and December, but these were not solely explained by the abundance of *Planktothrix*, suggesting other factors may contribute to toxin presence. This prompted further investigation into whether other cyanobacteria species or environmental conditions in the water column were influencing microcystin production. LefSe-LDA analysis supported this hypothesis, indicating that genera such as *Cyanobium* and *Aphanizomenon* could also be involved in microcystin production. These findings suggest a more complex interplay of species and environmental factors in driving toxin production than previously thought.




Total microcystins (ng/l)
Microcystins
150
100
50
0
February
March
April
May
June
July
July_end
August
September
October
November
December

WP1 - Pipeline for High frequency Image-based Phytoplankton monitoring of Lake Geneva

Mathilde DUGENNE, Irene MUSCAS, Mridul K. THOMAS, Bastiaan IBELINGS

As part of the work package 1, we aimed at understanding the environmental conditions leading to phytoplankton blooms in Lake Geneva. To that end, we developed a series of protocol in the laboratory using commercially available imaging instruments (CytoSense, FlowCams) to monitor key phytoplankton populations. A first protocol has been uploaded online at https://www.protocols.io/workspaces/meco_alga to ensure data reproducibility and foster potential collaborations. Samples collected on the platform LéXPLORE from September 2024 until now were imaged to develop these protocols and constitute our primary datasets to train machine learning algorithms able to recognize the different species present in the lake. We started building image libraries that will be used as training sets for the algorithm, including that of the main blooming species *Planktothrix rubescens*, *Mougeotia gracillima* or *Uroglena* sp. The libraries are available at https://ecotaxa.obs-vlfr.fr/gui/prj/14791 and will be updated regularly with new images acquired daily (on FlowCams) or even hourly (CytoSense) on LéXPLORE. These acquisitions will be processed in near real-time at the University of Geneva to follow the high frequency dynamics of phytoplankton both at the surface and at multiple depths (between 0 and 56 m) starting next week. In 2025, we will be testing different algorithms and comparing their accuracy to provide robust estimates of phytoplankton abundance, size distribution and species composition through time. We will pair these datasets with environmental data (nutrients, light, temperature, zooplankton) to understand what factors (abiotic or biotic) drive the succession of different species in Lake Geneva as well as blooms onset and demise.

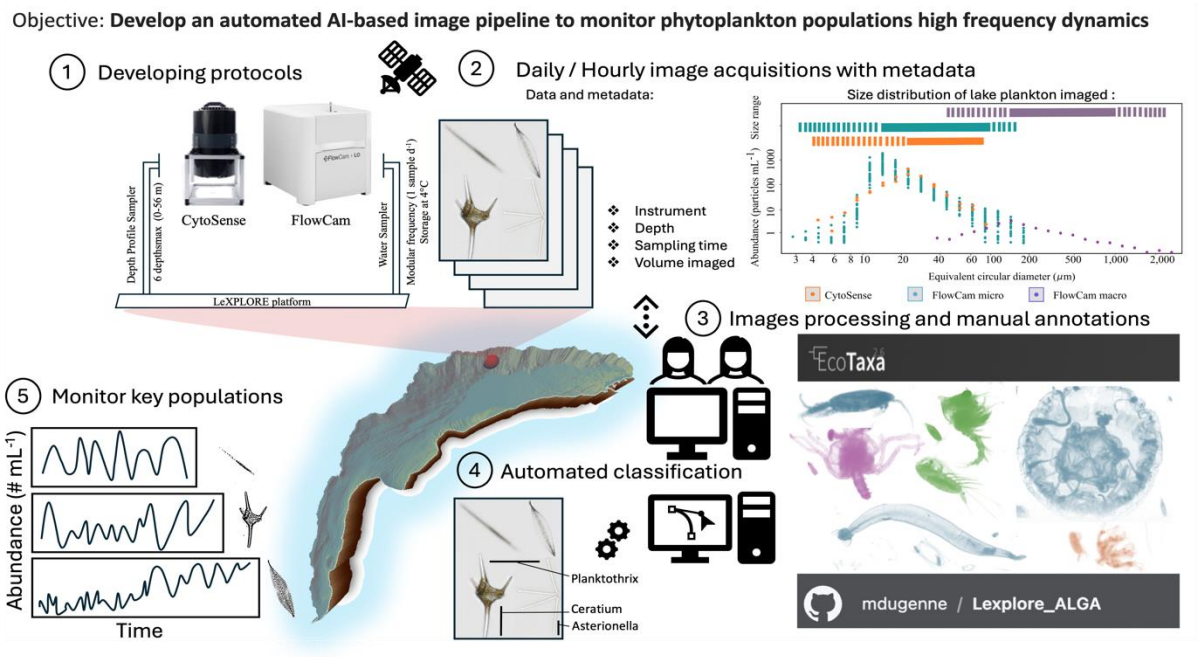


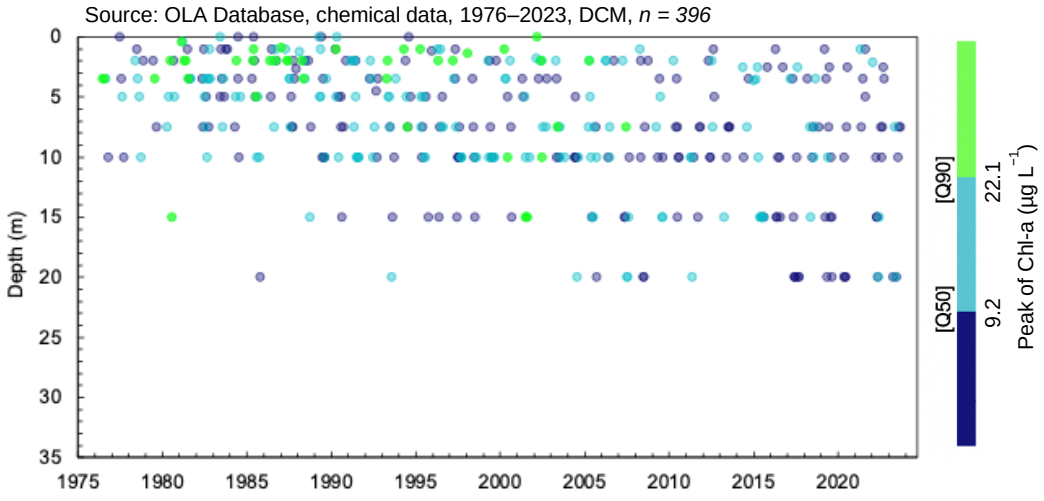
Figure 1: Illustration of the imaged-based pipeline used to monitor key phytoplankton populations in lake Geneva. The current workflow includes 5 major steps, consisting in (1) developing experimental protocols to image phytoplankton using commercially available instruments (CytoSense, FlowCams), (2) acquiring images, along with their metadata, in near-real time on a daily (FlowCams) or hourly (CytoSense) time-scale on the platform LéXPLORE, (3) automatically processing images to extract count, size, and taxonomic information, (4) implementing a machine learning algorithm to recognize key plankton species, and (5) providing near real-time datasets to database and lake stakeholders.

WP2 PROGRESS

WP2 – Understanding Deep Chlorophyll maxima in Lake Geneva

Orlane ANNEVILLE, Stéphan JACQUET, Frédéric SOULIGNAC, Laura SOARES, Jonathan DEROT, Myriam TAMI, Marianne CLAUSEL, Antonin SOULIER, Galdwin LEDUC

The aim of this work is to provide information that will enable a better use of satellite data for integration into the warning model (WP2). The work concerns the prediction of the depth of the maximum phytoplankton abundance. This question has been addressed by analyzing in-situ data collected at SHL2 on Lake Geneva. The first steps were to determine the depth of chlorophyll-a (Chla) peaks, to record the dates of occurrence of deep chl-a maxima (DCM) and to analyze the long-term trends in the localization and intensity of Chla-peaks and DCM. A deepening of the Chla-peaks and a reduction of their intensity were observed (figure below). If the phytoplankton community was dominated by one species, the Chla-peak can be associated with a phytoplankton taxon. Results indicated that the dominance of *Mougeotia*, which might be a problem for fishermen, was associated with deep Chla-peaks. For other species that are potentially harmful to human activities (Cyanobacteria), the location of the peak fluctuated without any long-term trend. Secondly, we explored the possibility of using neural networks to predict the depth of maximum phytoplankton abundance. The results are not yet conclusive and further analysis is needed.



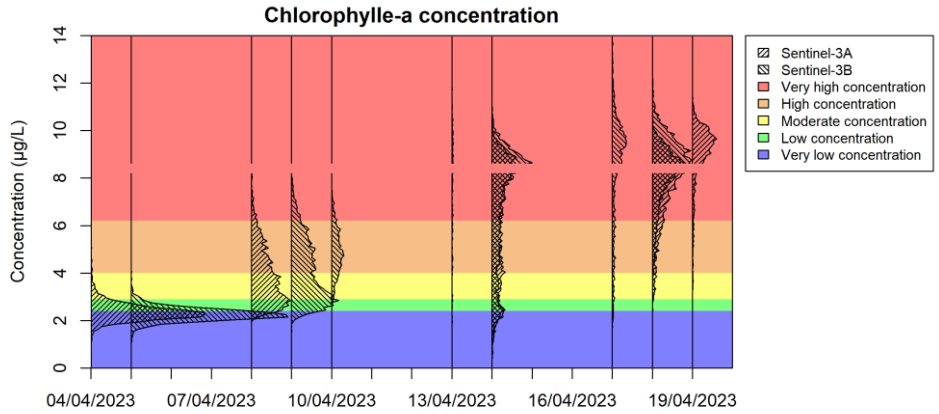
WP2 – Modeling the Impacts of blooms, Decision Support System

Frédéric SOULIGNAC, Orlane ANNEVILLE, Stéphan JACQUET

As part of the work package 2, a predictive model is being developed to assess the impact of phytoplankton blooms on the uses of Lake Geneva, together with a decision diagram in the event of a rapid proliferation.

Stage 1: Monitoring phytoplankton concentrations

Changes in surface phytoplankton concentrations are monitored using satellite data from the Aplakes project, which provides measurements of chlorophyll-a (chl-a) concentrations. Thresholds corresponding to five levels of concentration are used to establish alerts. This monitoring is supplemented by *in situ* data from the SHL2 station and the LeXPLORE platform, with daily updates.



Results of satellite monitoring of rapid surface proliferation from 4 April to 19 April 2023 (vertical histograms of chl-a concentration by date).

Stage 2: Modelling bloom movements

An advection-diffusion model based on Aplakes hydrodynamic predictions is used to predict the movement of blooms by transporting high concentrations of chl-a using surface currents.

Results and limitations

- For surface blooms, satellite data generally corresponds well with *in situ* measurements (SHL2 station), and the predictions of the movement of zones with high concentrations of chl-a are reliable in certain cases.
- However, for deep blooms, satellite data underestimate maximum concentrations at depth, making the assessment of blooms less accurate. In addition, displacement forecasts based on surface currents are not adapted to these deep blooms.

New approach: differentiating between surface and deep blooms

To improve the distinction between surface and deep blooms, two variables are currently being tested:

- Satellite data on water transparency (Secchi disc).
- Thermocline depth modelling data supplied by the Aplakes project.

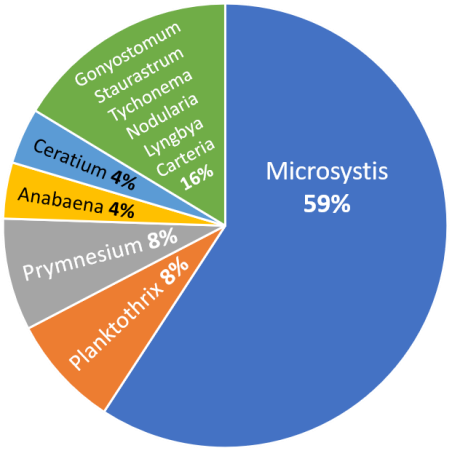
The aim of these analyses is to determine whether a chl-a concentration observed by satellite can be linked to surface development or a peak at depth.

WP2 - Scientific literature review on the Impacts of Blooms

Frédéric SOULIGNAC, Orlane ANNEVILLE, Thomas BOGNOLESI, Philippe DA COSTA, Jean-Marcel DORIOZ, Bastiaan IBELINGS, Alexandre RICHARD, Laura SOARES, Brigitte VINÇON-LEITE, Stéphan JACQUET

As part of the work package 2, a systematic review of the scientific literature is being carried out to analyse the impact of phytoplankton blooms on the uses of lakes and reservoirs. Initially, this review identified 966 articles using keyword searches in the Web of Science and Scopus databases. After an initial selection based on titles and abstracts, 129 articles were retained. An in-depth analysis resulted in 63 articles being considered relevant, plus around twenty additional articles from the bibliographic references of the selected works.

With the exception of two studies published in 1967 and 1980, the majority of the articles analysed date from the late 1990s to the present day and cover 46 countries. Phytoplankton blooms with a significant impact on lake uses are mainly caused by cyanobacteria, particularly *Microcystis* (59% of cases), although other species such as *Ceratium* and *Prymnesium* are also mentioned.



Microalgae involved in blooms that impact lake uses

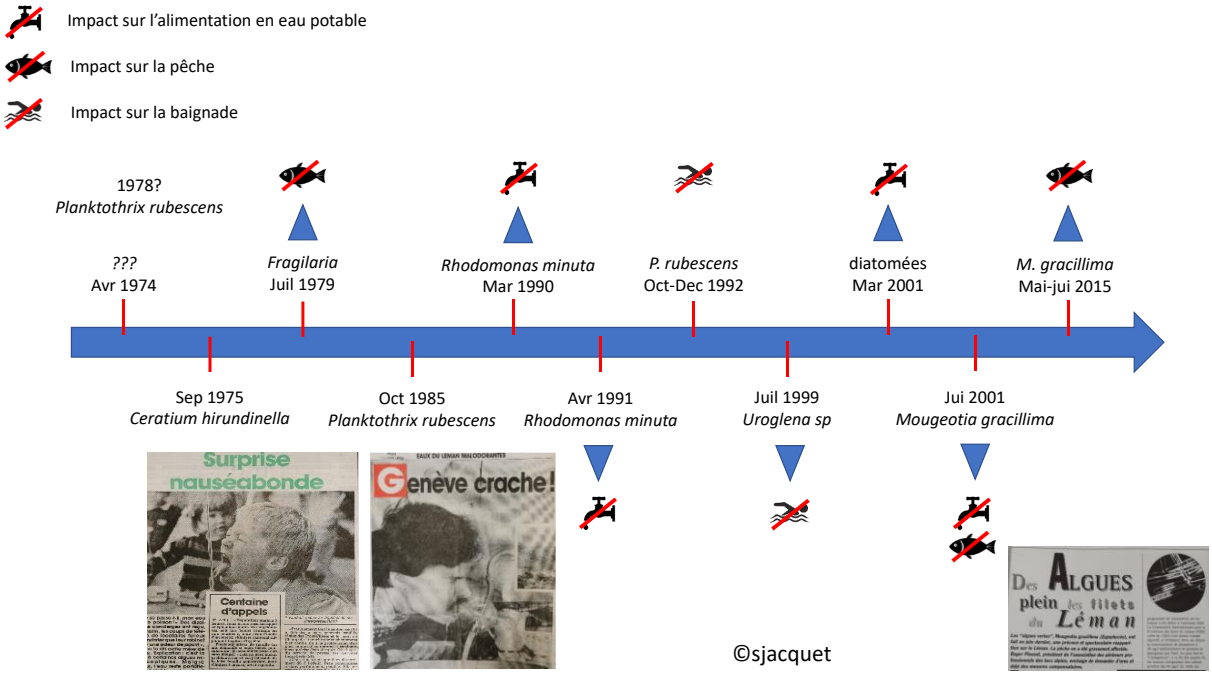
The impact of alga blooms on uses is evenly distributed between recreational activities, drinking water supply and fishing. Ten articles provide estimates of the associated costs, including issues such as public health, reduced water consumption, purification costs, loss of recreational days, reduced income from fishing and clean-up costs.

At the same time, certain beneficial effects of blooms have been identified. These include a reduction in mercury concentrations in phytoplankton, a substantial food supply for juvenile fish, the production of biological oil by pyrolysis, an increase in the volatilisation of polycyclic aromatic hydrocarbons (PAHs) in shallow lakes, and the production of the food supplement Klamath (from *Aphanizomenon*).

WP2 - Grey literature on the Impact of Blooms

Stéphan JACQUET, Frédéric SOULIGNAC

As part of the work package 2 dealing with assessing the impact of algal blooms on ecosystem services, an effort is made to find in the local and grey literature (newspapers, reports, etc.) the trace of algal blooms that occurred in Lake Geneva in previous decades. This historical research in a variety of available archives is still ongoing but we already found that such events occurred at several occasions and concerned different taxa such as *Rhodomonas minuta*, *Planktothrix rubescens*, *Mougeotia gracillima* or again *Uroglena* sp, i.e. species likely to bloom again in the future. We started proposing a figure (not disclosable) summarizing our findings as shown below. In 2025, a report (deliverable) will be proposed.



WP3 PROGRESS

WP3 - Public Perception of Blooms

Alexandre RICHARD, Pascal DA COSTA, Chloé DUYME

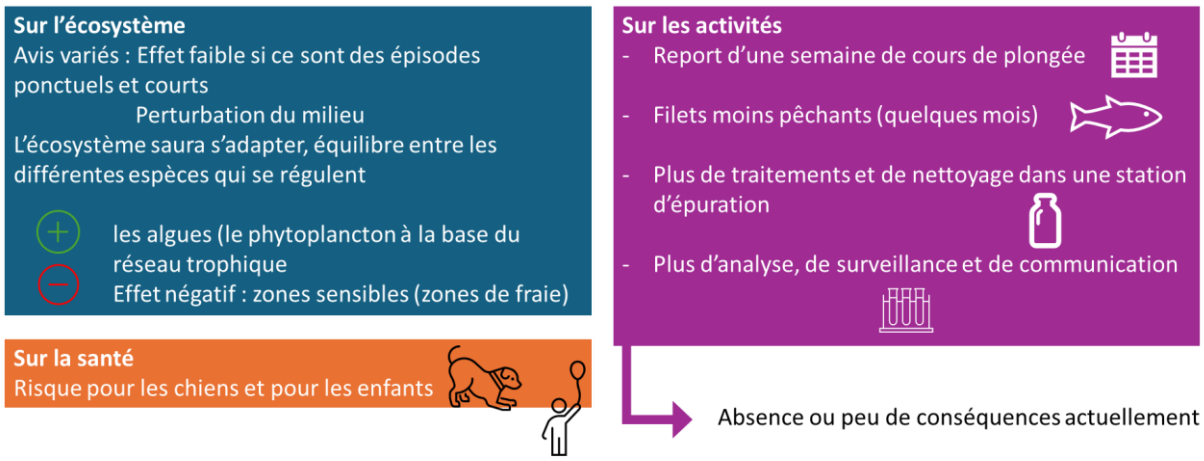
The work carried out on WP3, dealing with algal bloom perception by the population, in 2024 had a dual objective:

1. To characterise the population basin of the Lake Geneva territory through the collection of various georeferenced data (division into municipalities, urbanization, numbers, age structure, labour force rate, socio-professional categories, political colours,...);
2. Carry out a preparatory survey for the attention of the main actors of the Lake Geneva basin with a close link to the ecosystem services of the lake.

The survey work took place in the form of qualitative interviews lasting 1 to 3 hours, during which the people were questioned about their relationship with the territory, their attachment to Lake Geneva, their understanding of the issues related to the lake, and in particular the challenges raised by the algal blooms. The questionnaire then focused on the solutions envisaged to deal with these algal blooms.

A restitution seminar bringing together the interviewees and several contributors of the ALGA project, allowed the participants to further reflect on the different services impacted and to work on future scenarios of aggravation of these phenomena, trying to assess the main threats and possible solutions.

The main results of the survey carried out at the level of 21 structures in the Lake Geneva basin and relating to the impact of algal blooms are summarized below:



WP4 PROGRESS

Work on WP4 still to begin