Closer to Cayuga's Waters

Cayuga Lake is one of the landmarks that make Ithaca, NY so special. Our lake is a great place for swimming, boating, and fishing in the summer. It makes our climate a bit milder and contributes to the region's natural beauty. But in recent years Cayuga has been threatened by the invasive species *Hydrilla verticillate* and the increasing presence of cyanobacteria (also known as Harmful Algal Blooms or HABs). A network of volunteers organized by the Cayuga Lake Watershed Network (CLWN) monitors the lake for any signs of these threats. The Community Science Institute (CSI) trains volunteers for surveillance and HAB sample collection. Many other non-profits and governmental organizations actively participate in the Hydrilla Task Force. Your team will try to help them in improving the efficiency of these efforts.

Please focus on

- either Hydrilla (*any two* of the problems 1, 2, and 3)
- or HABs (problems 4 and 5).

In addition to a detailed description of your mathematical model, we ask you to provide a one-page non-technical summary addressed to CLWN or CSI representatives, who will be among the judges evaluating your submission.

Hydrilla is a very aggressive submersed perennial plant, which grows rapidly, spreads easily, and displaces native vegetation. One of its distinctive features is the ability to form potato-like "tubers" in the bed of the lake. These tubers store food, allowing the plant to regrow after the winter. Even if the plant is eradicated above ground, the tuber can remain viable for 7 to 10 years. This makes the mitigation measures particularly difficult. Hydrilla was first spotted in Cayuga Lake in 2011 and despite eradication efforts has been found at various locations in & around the lake in 2013, 2015, 2016, 2018, and 2019. All affected areas were either dredged or treated with chemicals, making it necessary to continue monitoring the treatment areas for water quality and signs of re-emergence. (The effect of chemicals on tubers is more varied and their elimination typically requires many years of treatment.)

1) You are asked to model **a multi-year spread of Hydrilla** throughout Cayuga Lake in a hypothetical scenario where it is left untreated. Please keep in mind that boats could play a major role in this spreading since they might transport small fragments of a plant to other parts of the lake.

2) CLWN has about 40 volunteers participating in monitoring efforts for possible Hydrilla spread & re-emergence. This includes monitoring (a) all previously treated areas, (b) the untreated areas nearby, (c) the rest of the lake, and (d) periodically inspecting the boats at various marinas & landings along the shore. You are asked to provide recommendations on how to split the volunteers' efforts among these tasks.

3) Monitoring "tuber banks" at previously treated sites is a particularly work-intensive task, usually handled by professionals. The procedure involves repeatedly removing small samples of the sediment ("cores", about 187 cm^2 each) and then counting the number of tubers found in each core. A density of 42 or more tubers per m^2 is considered high, indicating that there will be many Hydrilla plants at this site next summer. It is common to analyse 30 cores at each site. But as the chemical treatment continues and the density of viable tubers decreases, it becomes harder to use the numbers observed in different cores to infer the overall picture. You are asked to suggest an algorithm for adaptive decisions on when to request additional core samples.

HABs are transient events occurring when cyanobacteria start multiplying very quickly, often making small patches of the lake near the shore look like a spilled green paint or a pea soup. More importantly, HABs also release toxins, some of which can be extremely dangerous for people and animals. Since there are no reliable methods for a scalable treatment, the main approach is to identify HABs quickly – and then notify the public to avoid the affected portions of the shore until they disappear.

Unfortunately, a visual inspection of potential HABs is insufficient (a similar appearance can be often due to harmless Algae), which makes it important to collect a sample and promptly transfer it to CSI for testing. All test results are then communicated to the general public on the CSI website and through weekly announcements.

4) In 2021 CSI relied on a group of 93 volunteers to monitor about 57% of the lake shore. As you can see from the table, the number of identified HAB events has been steadily increasing in recent years. But since the surveillance efforts were growing too, what can we claim about the rise in the **total** number of HABs (including those that were not spotted)?

Year	percentage of the lake shore monitored	confirmed HAB events
2021	57%	102
2020	53%	78
2019	47%	67
2018	31%	40

The dataset for this table is here.

Note that the volunteers select their personal responsibility zones (shown in grey on this map), which they survey at least once a week (usually Sunday-Tuesday). Aside from these regular surveys, a volunteer might be also asked to do a spot check when a member of the general public reports a suspected HAB in or near that volunteer's zone. You are asked to estimate the number of HAB events that *might have been missed* by these monitoring efforts in 2021.

5) There is a general scientific consensus that HABs are facilitated by high concentrations of phosphorus and nitrogen nutrients, warm water temperatures, and direct sunlight. The primary source of nutrients is runoff into tributary streams that occur during rainstorm events. You are asked to see which factors, or combinations of factors, are most strongly associated with HAB events on Cayuga Lake. You can use CSI's long-term datasets for nutrient concentrations in the tributaries of Cayuga Lake and local climate data such as that provided through PRISM.