Hague & Gunflint Lakes: Monitoring Report

Friends of Cortes Island

Text prepared by Rex Weyler With data and analysis from the "Water Monitoring Program, Hague and Gunflint Lakes, 2014-16"; FOCI; Vancouver Island University; and BC Ministry of Environment.

Hague Lake from Mansons Lagoon looking southeast toward Baker Passage and Twin Island; Gunflint Lake drains through Hague into the lagoon, a 13.6 km2 watershed.

2017

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Contents

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1. **Summary**:

IN 2014, HAGUE AND GUNFLINT LAKES experienced an historically large spring algae bloom, causing fish die-off and a noxious smell. Lakeside residents and Friends of Cortes Island (FOCI) began research into lake ecology. In 2015, the BC Ministry of Environment and Dr. Eric Demers from Vancouver Island University, helped FOCI design a long-term lake monitoring program.

We have reviewed earlier reports on Cortes and reports from other other communities facing similar challenges with their lakes. We have developed an understanding of long-term and annual lake cycles and monitored the lakes for oxygen, nutrients, and bacteria.

The data collected to date tell us that the human settlement around these lakes have contributed — through land use changes, animal husbandry, and septic flow — to heightened nutrient and bacterial loading. These factors contribute to algae blooms, species diversity risk, health risks, and accelerate the long term transformation of the lakes toward a eutrophic (over-productivity) state.

We have learned from the literature from other lakes, and from our own lake data, that the community can take certain actions to mitigate these risks, and restore the lakes to a healthier state. Those actions include septic maintenance; careful livestock management, lakeshore replanting and maintenance, limiting nitrogen fertilizers, eliminating phosphate soaps, and applying biological-remediation systems to help purify water runoff entering the lakes.

2. **Introduction**

The 2014 algae blooms in Hague and Gunflint Lakes resulted in noxious odours, caused by decomposing algae. Some swimmers reported higher than usual irritations and “clouds” of algae through the summer. Lakeside residents observed fish die-off along the northeast and northwest shorelines of Hague Lake.

During the following spring of 2015, the algae blooms appeared again, less extensive, but noticeable, with several days of annoying smell and bad taste, with various blooms sustained through the summer months. The blooms during 2016 appeared noticeably worse than 2015, but not as extensive as 2014.

Following the initial blooms, several lakeside residents asked Friends of Cortes Island (FOCI) to help research and report on the algae blooms. FOCI petitioned for local community and government support, and began investigating the health of the lakes.

In April, 2014, Cortes residents Rex Weyler and Christian Gronau collected water samples, sought advice from other biologists, and identified some of the algae species present in the lakes. Due to the common presence of **Volvox** algae, some of the biologists thought that Volvox might be the large bloom. We also found a significant presence of dinoflagellates and diatoms. These three families of organisms are non-toxic to humans, but can deplete the lake's oxygen and kill fish or other lake species. We also observed the "blue-green" bacterium ("cyanobacterium") , *Nostoc sp*., which is toxic and can cause human health concerns. Previous monitoring efforts revealed **E. coli** bacteria, which can cause human health concerns.

In 2014, with the help of the BC Ministry of Environment and Dr. Eric Demers from Vancouver Island University, FOCI began a long-term lake monitoring program to determine the extent of annual lake algae blooms, the state of these lakes, and the risk for future large blooms and contamination. Some actions have been taken — septic information provided to the community, some septic system upgrades, and replanting the lakefront in some areas — although we will need more time to monitor the lakes to assess the success of these actions. In the meantime, the collected data provide useful information. In the Fall of 2015, the Ministry of Environment published a draft report "Water Quality Monitoring Program, Hague and Gunflint Lakes, 2014-15," providing a preliminary summary of data, analysis, the state of these lakes, and community response recommendations.

This FOCI report serves as an update on that preliminary report, a summary of findings to date (including data and analysis from earlier reports), and some recommendations of actions that the community and individuals within the Hague-Gunflint watershed can take to help minimize these algae blooms. With informed action we can mitigate the negative impacts of algae and bacteria blooms on wildlife, lakeside residents, the larger community, and on visitors to Cortes Island, who enjoy these lakes.

3. How Lakes change

Lake ecosystems provide an example of "dynamic homeostasis" in nature, a delicate balance of fluctuating elements and sub-systems, including seasonal changes, wind, light, air and water temperatures, nutrient flows, water currents, plants, animals, micro-organisms, contamination, and chemical interactions. Lake productivity and species diversity are finely regulated by these fluctuating factors.

A lake is a relatively stationary ("lentic") ecosystem that shares some features with flowing ("lotic") rivers and streams. By definition, a lake differs from a "pond," in which light reaches the entire bottom surface, whereas in a lake light diminishes with depth below the threshold to sustain plants or phytoplankton. Some species, which do not appear in ponds, are specifically adapted to live below the light threshold in lakes.

To understand the risks to our lakes, and how we might respond to algae blooms or bacteria counts, we benefit by understanding some fundamental principles about lakes and how they change over time.

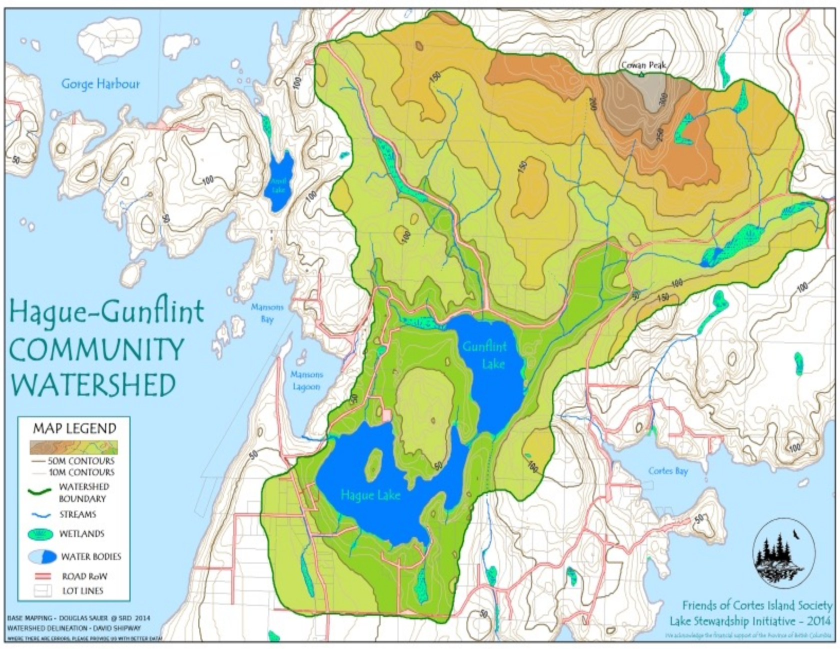
A lake is not a static "thing," but rather a living network of processes. A stable ecosystem is not "fixed," but rather it changes continually within certain limits. A lake changes day-to-day, in an annual cycle, and in a long biophysical evolution over centuries.

A lake is the product of the watershed, or drainage basin, in which it exists. Its status is influenced by rainfall cycles, climate, geology, soil content, shoreline shape, plant and animal inhabitants, sunlight, wind, and natural nutrient cycles. A human community within the watershed will also influence a lake through land use changes and the waste flow of nutrients, bacteria, and pollutants.

Long term change:

Our lakes were carved by glaciers, and the receding glaciers left behind these lakes, filling with sea water when sea level rose (during warm periods) and converting to fresh water from rainfall after the seas dropped (in cooler periods). Certain lakes, such as Powell Lake — due east of Cortes Island on the mainland — are so deep that some seawater remains on the bottom, creating unique ecological habitats. In our lakes, the cutthroat trout are decedents of sea-going salmonoids, left behind when sea levels dropped.

Our lakes on Cortes are filling with silt at the rate of about 1-millimetre per year, or one meter every thousand years. Over time, lakes fill with silt. Hague and Gunflint have been filling for almost 10,000 years, so there are about ten meters of fine silt on the bottom of our lakes. In another 10,000 years, there will be another ten meters of silt.



The 13.6 km^2 Hague-Gunflint watershed. The lake system is primarily fed through Gunflint lake, and drains from Hague into Mansons Lagoon. The underground water table also feeds and drains both lakes. (map by David Shipway)

Likewise, over time, lakes transform from being low-productive reservoirs of water, to moderately productive, full of life, and eventually become so overly-productive, that they may choke on their own growth. Lakes will eventually fill with silt, become highly productive with life forms, and become shallow swamps. This is the long-term fate of all lakes, until there is some new geological disruption, such as a major earthquake, sea rise, or another ice age.

In scientific language, a low-productivity lake is called "oligotrophic" and an overly productive lake is called "eutrophic." The process of changing from low, to medium, to high productivity is called "eutrophication." You may hear these terms used, but thinking simply about high and low productivity is good enough.

Annual cycles:

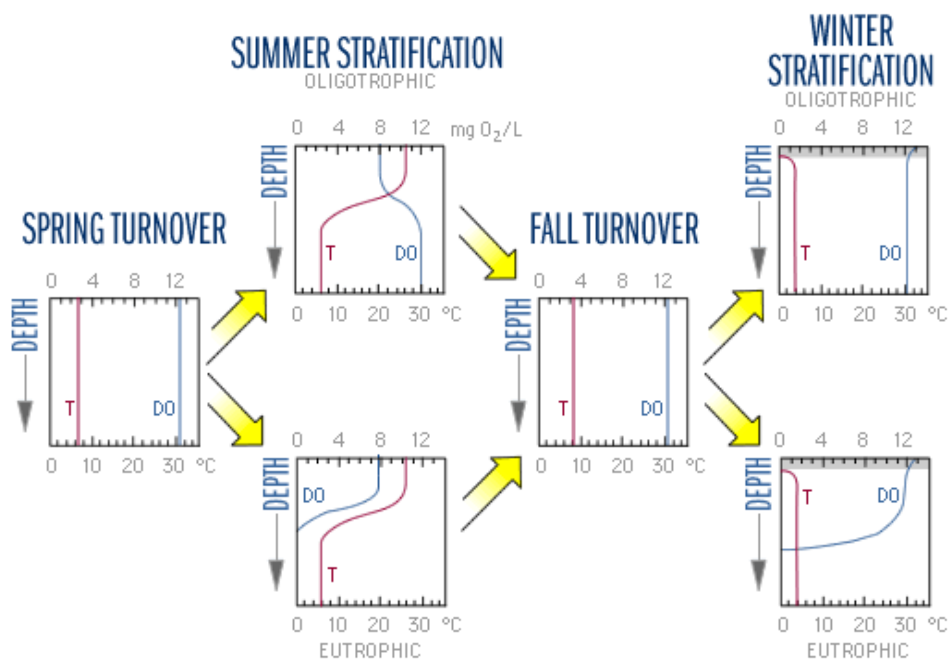
In the spring, as the ice melts (if there is ice), spring winds tend to stir the lakes, mixing the water, so that the temperature and oxygen levels ("dissolved oxygen") become fairly uniform, top to bottom. As the lakes warm in the summer, the water does not mix as much, the surface water warms, and the temperature remains cool toward the bottom. The lakes "stratify" or separate into temperature and oxygen zones. Fall winds stir the lakes again, and they become more uniform. During the winter, the temperature remains fairly uniform, although surface water may grow cooler, and oxygen may be reduced at lower depths until the spring winds stir things up again.

Annual Lake Cycles

for Low productivity (Oligotrophic) and High productivity (Eutrophic) lakes

Low:

High:



Temperature and oxygen graphs, for a typical lake, through the year, at different depths. (Temperature in red, with the scale below the graph; oxygen in blue, with the scale above the graph). These graphs represent two types of lakes: a low-productivity lake ("oligotrophic") on the top, and a high-productivity lake ("eutrophic") below. Both types of lakes appear similar in the spring and fall.

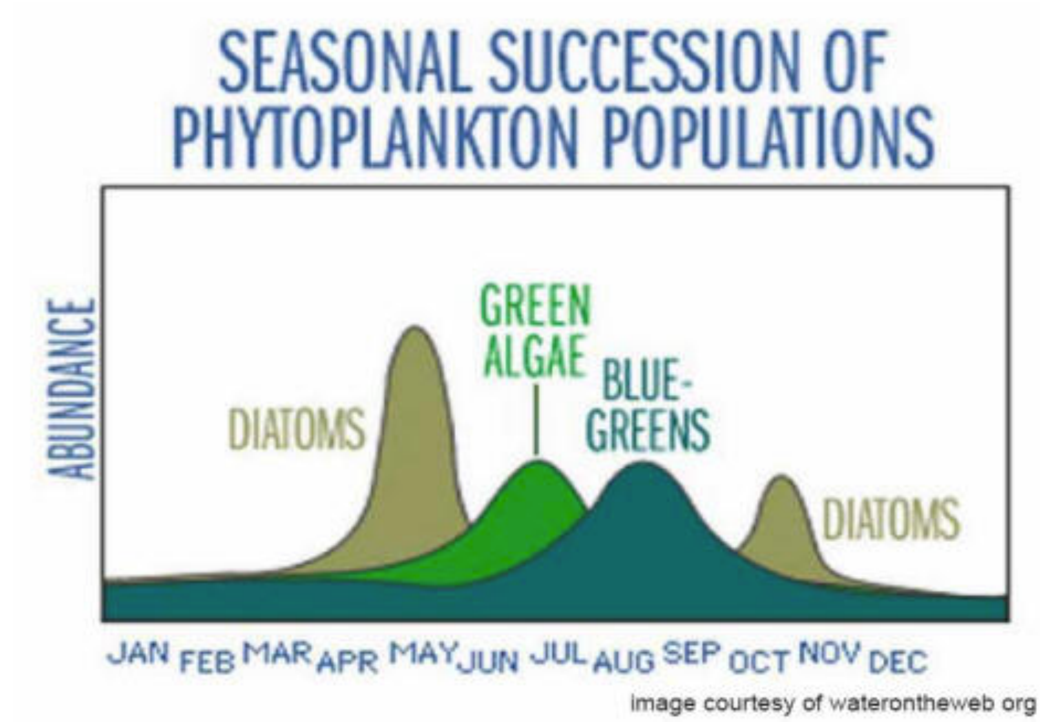
You will notice some interesting differences through the seasons. In the spring, when winds stir the water ("Spring Turnover"), lakes tend to be uniform, but in the summer, the temperature warms at the surface. In a low-productivity lake, oxygen increases with depth, since some oxygen passes into the atmosphere or is consumed near the surface by organism decomposition. In a high productivity lake the oxygen will decrease with depth, since high-productivity lakes have more oxygen-consuming animal life. In the fall, winds again mix the lakes and make them more uniform. In the winter, in a low-productivity lake, top charts, temperature drops near the surface, but otherwise the lake will remain fairly uniform. However, in a high-productivity lake, in the winter, oxygen levels may drop with depth due to decomposition of summer growth.

Our Hague and Gunflint lakes follow a moderately low-productivity pattern (top row charts) but also have shown a winter oxygen drop with depth, suggesting a lake in transition from low to higher productivity, likely due to nutrient loading. (See details in section 4, Lake Productivity Status, below, page 8.)

Algae and diatom blooms:

Micro-organism blooms are influenced primarily by available light, water temperature, water flow, and available nutrients, and they tend to occur in an annual cycle: Diatoms in the spring and autumn, green algae in early summer, and blue-green bacteria in the warmer summer months.

Diatoms are single-cell phytoplankton (light-consuming organisms) that form colonies in various shapes (ribbons, circles, spirals, and stars). Green algae collect solar energy with chlorophyll. Bluegreen bacteria (cyanophyta) are a photosynthetic, prokaryotic (no cell nucleus) bacteria. Each of these phytoplankton persist through the year at a low level in our lakes. Although natural cyanobacteria exist in lakes, bacteria such as *E. coli*, flow into the lake from either human or other animal sources.



The size, or peak, of these blooms vary with the climate and nutrients. The most significant nutrients, which feed algae blooms, are phosphorus and nitrates. Nitrates concentrated at high levels can cause health effects in people, impair fish immune systems, and kill some aquatic species. Although our lakes do not experience these extreme levels yet, they do contain measurable levels of bacteria, and high levels of nutrients that feed algae blooms (See Section 4, Lake Productivity Status, below, pg 8.)

Human impact on lakes:

Wild animals contribute nutrients and bacteria to the lakes, historically at levels that the ecosystem can metabolize or process. Human disruption in a watershed tends to be at a larger scale and appears as a primary source of nutrient loading, pollution, land-use changes, and invasive species:

Nutrient loading from:
- Nitrate fertilizers
- Nitrates and phosphates from human septic
- Nitrates and phosphates from pets and livestock
- Phosphates from grey water (phosphate cleaners, etc.)

Pollutants, toxins:
- Bacteria from farm animals and human septic (including *E. coli*)
- Toxins from disposal (paint, cleaners, etc.)
- Herbicides and pesticides
- Oils and pollutants from automobiles and industrial sites

Land-use changes
- Clearing on lakeshore or upland (removing plants that consume nutrients)
- Paving: roads, walkways, and construction that disrupt natural water flow
- Erosion from construction, clearing, or over-use

Invasive species
- Introduction of invasive animal species into lakes and streams
- Introduction of plant species from boat bottoms, or as ornamental plants
- Household pets

Most or all of these impacts occur in the Hague/Gunflint watershed, but we have opportunities to reduce them: (1) reduce and limit **nutrient loading**, primarily from septic, fertilizers, livestock, and household cleaners; and (2) reduce and limit **bacteria** loading from septic, livestock, and pets. (see Recommendations, page 20)

(*Hague, Gunflint lake report, FOCI, Weyler, 2017 .. 6*)

Nutrient loading leads to accelerated productivity, called **eutrophication**. Large algae blooms can signal the early stages of this change. Nutrient loading can lead to oxygen depletion and lake dead zones, and can favour certain organisms and harm others. All the living organisms in the ecosystem, including us, contain nitrates and phosphates, essential elements of organic molecules. All household septic systems include a flow of these nutrients, and those that reach the lake feed diatom, algae, and bacteria blooms.

A typical eutrophic — over-productive — lake. The algae blooms are fed by phosphorus and nitrogen that can come from wildlife, human septic, fertilizers, and phosphate cleaners. The algae bloom is limited by the presence of these nutrients. As the algae dies off, it depletes oxygen in the lake, potentially eliminating other species, causing the lake to become swamp-like. Although this trend appears commonly worldwide, simple solutions exist.

Algae blooms favour certain warm water temperatures in calm water. As a result of climate change, warmer global temperatures and disrupted wind cycles can encourage algae growth in lakes, and this appears to occur worldwide.

Algae blooms virtually killed Lake Erie, between Canada and the US, and likewise Green Lake in Washington State, Fern Ridge Lake in Oregon, Lough Neagh in the UK, Lake Taihu in China, and so forth around the world: thousands of dead or swampy former lakes with accelerated eutrophication aggravated by human agricultural and septic runoff.

Rosalind and Marl lakes in Ontario, St. Mary and Cusheon Lakes on Saltspring Island, and Village Bay Lake on Quadra Island have experienced recent, severe algae blooms. In the summer of 2016, BC Northern Health issued an advisory for Prince George area lakes due to a blue-green bacteria bloom that appears as a surface scum. Climate warming and human nutrient loading appear as primary causes of these changes.

Here on Cortes Island, we have allies, support, good advice, and we are not alone, but we have a serious challenge ahead of us to restore the health of Hague and Gunflint lakes. The biologists, with whom we have consulted, told us that we are starting our responses earlier than most communities, and that this will work in our favour.

Here, below, is a summary of the historical record of our lakes, which we have reviewed:

4. Lake Studies and Monitoring: What we've learned about our lakes

During the 1920s, the watershed was logged. Sometime before 1950, loggers modified the channel between the lakes and the outflow to Mansons Lagoon to allow log transport to Mansons Bay. In 1956, the inlet through the Hansen Farm, now Linnaea Farm, was modified for irrigation. In 1988, the Canadian Department of Fisheries began a salmon enhancement project in Hague Lake, introducing coho salmon to the system, which caused some concern regarding potential impact on the local cutthroat trout.

BC Ministry of Environment Study, 1989:

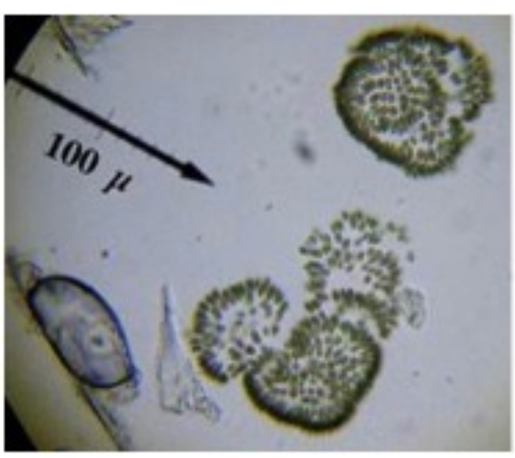
The earliest official study of these lakes appeared in 1989: "Reconnaissance Survey of Gunflint Lake," written by D.M.V. Coombes, with Peter Law (Fisheries biologist), and J.A. Balkwill (BC Resource Inventory), commissioned by Recreational Fisheries Branch, BC Ministry of Environment. At this time, there were seven dwellings and five docks on Gunflint Lake. There were obstructions on tributary streams and a logjam, still recognizable today, at the outflow.

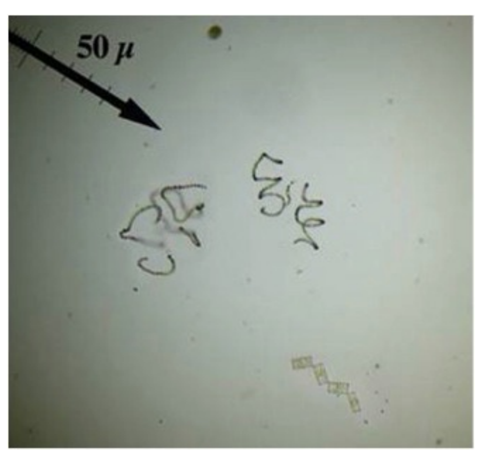
The report noted, "many homes on septic tanks around Hague and Gunflint lakes." Although they did not search for septic problems, they did warn that "Faulty systems could contaminate the lake with biologically active materials and inorganic nutrients." They also warned that some tributaries remained accessible to cattle and horses, potential sources of bacterial and nutrient pollution.

The surveyors observed stickleback, sculpin, cutthroat, and stocked coho in the lakes. They sampled temperature and dissolved oxygen in Gunflint Lake during June, 1989, and found a fairly common summer-lake pattern, with temperature dropping from 21°C at the surface to less than 5°C below 10 meters; and oxygen increasing slightly between 4-12 meters, likely due to algae production at that level, then decreasing slightly toward the bottom. Total Nitrogen levels ranged from about 0.27 to 0.38 mg/L (milligrams per litre). These readings suggested a lake system in a medium-productivity (mesotrophic) stage, not yet obviously tending toward dangerous eutrophication.

Recent studies:

In April, 2014, during the large algae bloom, we took water samples and found Volvox (a green algae), dinoflagellates, diatoms, and cyanobacterium, which is toxic to some organisms. The large algae bloom that spring indicated a high load of phosphates and nitrates in the lake, "nutrients," that supply the food necessary to feed these blooms.





Volvox algae (left) and cyanobacteria (Nostoc sp.) and diatoms (Tabellaria) from Hague Lake, collected in the summer of 2014. Microscope photographs by Christian Gronau.

The algae gives off oxygen as it grows, and then depletes oxygen in the lake as it dies and decomposes, accounting for the unpleasant smell and taste. The bloom has now repeated — at a slightly lower scale — over the last two years. There exists a risk that continued algae blooms could eliminate other species in the lakes and accelerate the process toward eutrophication, an over-productive lake tending toward swamp conditions.

Lakeside residents and FOCI contacted the BC Ministry of Environment and Dr. Eric Demers, lake biologist from Vancouver Island University. Demers and graduate student and Reanna Shelling visited Cortes during the summer of 2014 and took water samples from both lakes. Local residents helped gather samples, learned how to take samples, and have continued the monitoring program with support from FOCI. We have continued to collect and analyze water samples through 2015, 2016, and early 2017.

This monitoring program has provided a profile of lake conditions and status, including an analysis of the micro-organisms — algae, bacteria, and plankton species — in our lake. We have also measured water clarity, lake acidity, oxygen levels, and nutrient levels. We have now completed a first set of tests to determine bacteria source — wildlife, humans, and livestock — that will help us focus our response.

Dr. Rosie Barlak, Environmental Impact Assessment Biologist at the BCMinistry of Environment in Nanaimo, helped analyze the samples, and drafted a report based on the results: "Water Quality Monitoring Program, Hague and Gunflint Lakes, 2014-15." Dr. Barlak visited Cortes Island in August 2015, and met with community residents to answer questions regarding the data and the report.

Dr. Barlak and Dr. Demers told the community that these lakes remain relatively healthy, although they are experiencing accelerated algae and bacteria bloom cycles and that there is risk that the lakes could change to a dangerously over-productive, eutrophic state.

5. Lake productivity status

The Ministry of Environment report explains that "Challenges to water quality management on Hague Lake and Gunflint Lake include phosphorous loading from non-point sources. Excess phosphorous can cause spring and summer algal blooms and supports the growth of aquatic vegetation. When vegetation and blooms die off and settle to the bottom, this can lead to oxygen depletion in the lake, caused by a proliferation of bacteria, which thrive on decaying matter and can exhaust the oxygen supply."

"Point source" pollution comes from residential or industrial effluent, for which the source is known. "Non-point source" pollution enters the lake through the groundwater, from unknown sources, including wildlife and human sources. Of course, all pollution comes from some source. The data tells us so far that human septic and livestock are two of the known sources.

"The amount of total phosphorous in a lake can be greatly influenced by human activities," warns the Ministry of Environment report. " If local soils and vegetation do not retain this phosphorous it will enter water courses, where it will become available for algal production."

" Challenges to water quality management on Hague Lake and Gunflint Lake include phosphorous loading … this can lead to oxygen depletion in the lake. "

Hague and Gunflint lakes remain in the medium-productivity level, not yet reaching the over-productive eutrophication stage, although the recent algae blooms and presence of fecal bacteria serve as warning signs. Here below are the results that tell us the productivity stage of these lakes.

Water Temperature

Water temperature affects the solubility of chemicals, the suitability of habitat for micro-organisms, and the effective reproduction of fish and other lakes species. As we have seen, lake water tends to be a unified temperature, top to bottom, during the spring and fall, when winds are strongest, and air temperatures less extreme. Lakes "stratify" in the summer and winter. In the summer, temperatures rise at the surface and drop with depth, and in the winter, lakes cool and may freeze at the surface.

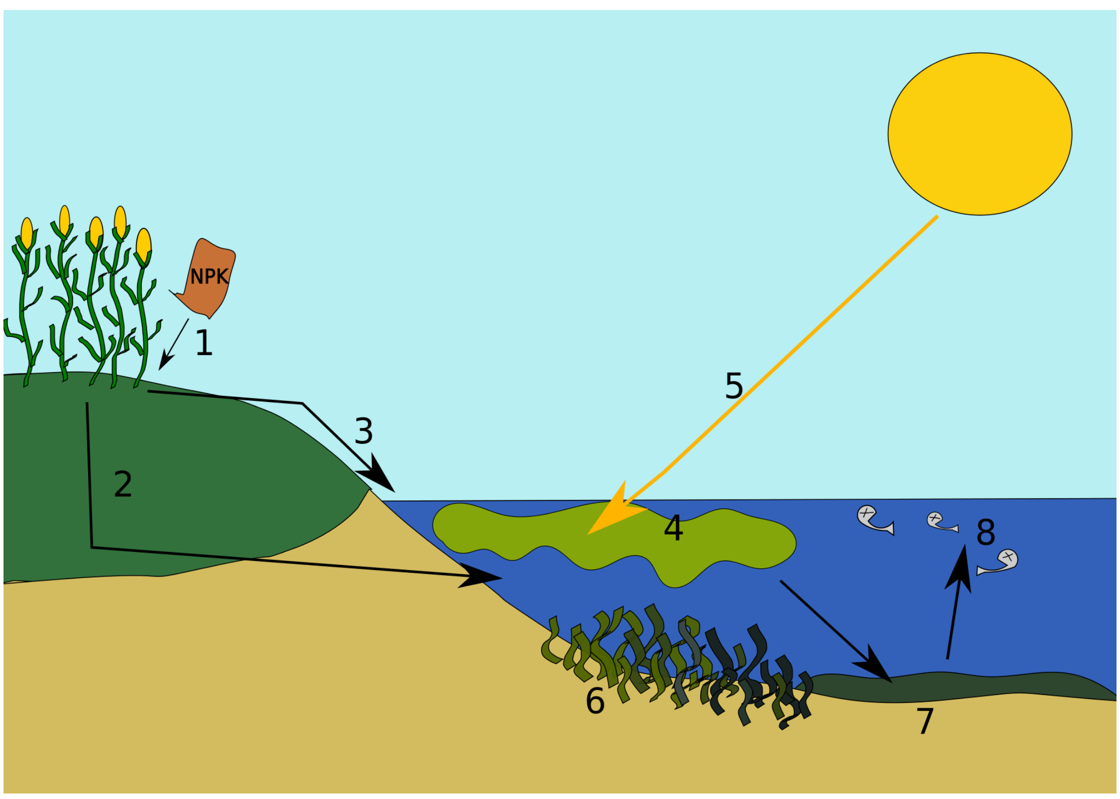
By early March, 2015 and 2016, both lakes were beginning to stratify with the arrival of warmer weather and milder winds. In Hague Lake, on March 8, 2015, the maximum water temperature was 8.3 °C near the surface, dropping to a minimum of 6.9 °C at 10 meters. In Gunflint lake, on this date, temperatures dropped steadily from 7.7 °C at the surface to 5.3 °C at nine meters.

Surface temperature peaks in both lakes at about 24 or 25 °C in late August, dropping to about 12 °C in late October, and reaching about 0 °C, freezing, in mid-winter. The mid-winter ice thickness has been declining in recent years due to the warming climate, although the lake surfaces froze in January and February 2017. In the winter, the lakes show a slight cooling near the surface due to cold air and ice. These temperature data support the conclusion that our lakes are in a medium-productivity stage.

Oxygen levels

Dissolved oxygen in water is critical for aquatic life. Oxygen enters the lakes from the air and from plant photosynthesis. When plants or animals die off, oxygen is consumed. As lakes become more productive (eutrophic), more organisms decay and consume oxygen, and lakes can become depleted in oxygen, causing more die-off.

Like temperature, oxygen levels stratify, vary with depth, in the summer and winter. The BC Ministry of Environment recommends that lakes be protected to keep oxygen levels above above five milligrams per liter (5 mg/L), the threshold for most fish species. On August 18, 2014, both Hague and Gunflint lakes were well stratified, with oxygen levels dropping below the 5 mg/L threshold near the lake bottoms. Both lakes showed about 8 mg/L at the surface, then a dramatic increase in oxygen between 4 and 9 meters, indicating large algae blooms at that depth, which gives off oxygen while growing. This same bloom will deplete oxygen as it dies and decomposes.



Nutrients and Oxygen: 1. Nutrients enter the soil from wildlife, nitrogen fertilizers, livestock, or septic. 2. Nutrients can remain in soil for years, then .. 3. seep into the lake. 4. Excess nutrients feed algal blooms, which .. 5. block sunlight, so that .. 6. some plants below die from lack of sunlight. 7. When the algae bloom dies, sinks, and decomposes, it depletes lake oxygen. 8. Larger organisms, such as fish, can suffocate, and the lake may transform to a eutrophic swamp.

In the fall, dissolved oxygen measurements increased at the surface of both lakes to 10 mg/L, likely due to stirring of surface water by the wind. In Hague Lake, this oxygen level remained consistent throughout the lake, and only declined slightly toward the bottom. In Gunflint, a deeper lake, the oxygen level dropped off significantly after 9-meters depth, fell below the 5 mg/L threshold after 15 meters, and approached zero oxygen near the lake bottom. This stratification continued through the winter, suggesting a change toward higher productivity.

In the spring of 2015, dissolved oxygen levels were high in both lakes, over 12 mg/L at the surface, with Hague Lake dropping to 10 mg/L at the bottom, and Gunflint dropping to 0 mg/L. These readings suggest, at least in these recent years, that dissolved oxygen levels are sufficient in the optimum temperature zones for cutthroat trout. However, during a large algae die-off, decomposing algae could suffocate some fish eggs or small fry.

Phosphorus, nitrogen, and productivity (trophic) status:

In 2009, Earth systems scientist Johan Rockström and colleagues published "Planetary Boundaries" in *Nature* journal, showing that human activity has pushed seven essential systems – including biodiversity, temperature, ocean acidification, fresh water, ozone depletion, and land use – near or beyond critical tipping points. The seventh system at risk they named is the disruption of the world's nitrogen and phosphorus cycles.

Phosphorous and nitrogen are critical for organic molecules such as nucleic acids, phospholipids, adenosine triphosphate (ADT), and for DNA. All plants need phosphorous and nitrogen to build essential organic chemicals. Land and aquatic plants, root systems, and soil microbes, have specifically evolved to find and consume these nutrients.

In many coastal BC lakes, such as Hague and Gunflint, phosphorus is the nutrient in shortest supply, so monitoring phosphorus levels is important. As the Ministry of Environment report warns: "Total phosphorus (TP) in a lake can be greatly influenced by human activity." Research shows that in typical communities, the average person contributes over two grams of phosphate per day. This phosphorous typically arrives from septic, livestock, and phosphate cleaners.

Phosphorous is rare in elemental form because it easily combines with oxygen when exposed to air. In natural systems, phosphorous typically exists as phosphate: PO_4 in soil, and as H_2PO_4 in water. The measure "Total phosphorus" in water accounts for all the phosphorus in solution, available to organisms such as algae.

Phosphorus can have a secondary feedback effect by accelerating algae blooms that deplete the lake's oxygen as the bloom dies off. The low-oxygen environment causes lake sediments to release more phosphorus, which in turn feeds additional algae blooms. This is the sort of ecological feedback loop that can push lakes into an over-productive state.

Lake productivity ("trophic status") can be determined by measuring nutrients as "Total Phosphorus"; plant growth is measured as chlorophyll-a; and visibility as "Secci Depth," measured in meters, by lowering a black and white disk into the lake until it disappears. Chlorophyll-a and phosphorus are measured in micrograms per litre (µg/L). A microgram is 1-millionth of a gram.

Productivity **Trophic status**	**Nutrients** **Phosphorus**	**Plant Growth** **Chlorophyll a**	**Visability** **Secchi Depth**
low (oligotrophic)	1 - 10 µg/L	0-2 µg/L	> 6 m
medium (mesotrophic)	10 - 30 µg/L	2-7 µg/L	3- 6 m
high (eutrophic)	> 30 µg/L	> 7 µg/L	< 3 m

As phosphorus, algae, and chlorophyll increase, lake visibility (Secci Depth) decreases. For the protection of aquatic life, the BC Ministry of Environment recommends holding Total Phosphorus levels between 5 - 15 µg/L.

In the spring of 2014, 2015, and 2016, Total Phosphorus readings were collected at depths of 0.5 and 10 meters in both lakes, and at 17 meters in Gunflint. During 2016 Total Phosphosus and Total Nitrogen were recorded monthly throughout the year at 0.5m depth in both lakes. In the summer, both lakes appeared in the low (oligotrophic) or medium state, with the highest phosphorus reading of 11.3 µg/L in Gunflint, in the lower-medium range. However, in the spring, phosphorus levels in both lakes reached the high-productivity (eutrophic) levels, with the lowest reading of 38 µg/L in Hague Lake and some readings of over 45 µg/L in Gunflint. These high phosphorus readings appear consistent with the large spring algae blooms.

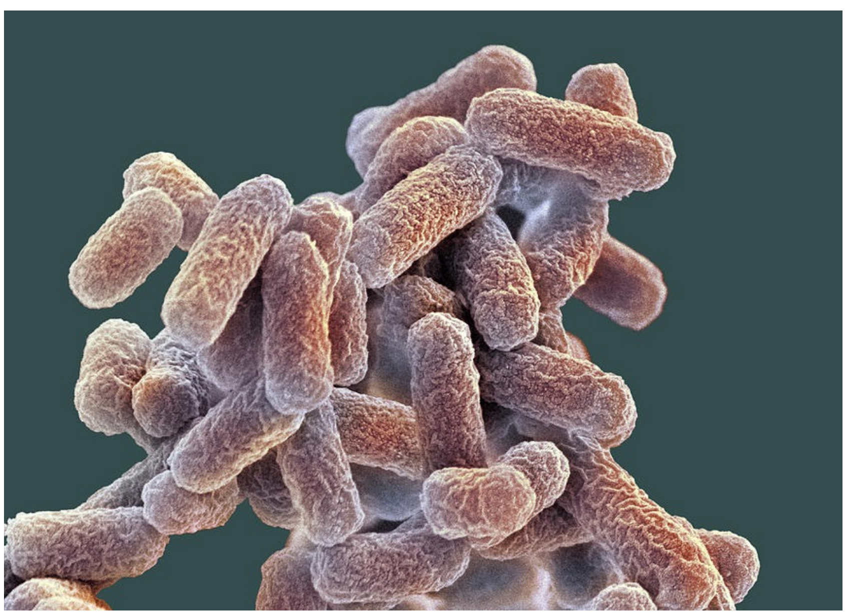
The chlorophyll-a readings were similar, with lower readings in the summer, and higher readings in the spring, especially in Hague Lake, likely due to the spring algae bloom, since Hague Lake was less stratified than Gunflint and therefore could cycle nutrients more readily through different depths.

Likewise, visibility in the lakes (Secchi Depth) decreased slightly in the spring, likely due to algae growth, and decreased again in the fall, possibly due to a fall algae bloom in Hague and perhaps augmented by high runoff from heavy autumn rainfall (264.9mm during October, compared to 7.4mm during August).

These readings tell us that Hague and Gunflint Lakes appear healthy, but in a transition phase from low to higher productivity, which serves as a warning sign. If nutrient levels continue to increase, and as global warming pushes temperatures higher, the lakes could be in danger of becoming overly productive, oxygen depleted, unable to sustain trout or other animal species, more dangerously contaminated with bacteria, and less suitable for human recreation or as drinking water.

Bacteria in the lakes

Human communities and their livestock not only contribute nutrients and feed algae blooms, but they also contribute bacteria to the lakes. The earliest tests for bacteria in our lakes were conducted from 1991through 1997, by Cortes residents Fred Zwickle and Ron Croda. They collected water samples from Hague and Gunflint and tested for coliform bacteria, both fecal and non-fecal forms. They received help from the Regional District, Zenon Laboratories in Surrey, and MB Research Laboratory in the US.



E. coli bacteria form in colonies. Testing laboratories count "Colony Forming Units per 100 millilitres of water." Bacteria arrives in the lake from wildlife and human sources. Photograph by Steve Gschmeissner.

Zwickle and Croda were particularly interested in coliform bacteria that enter our lake from wildlife, domestic pets, livestock, and from human septic systems. The presence of coliforms can be used to indicate hepatitis or giardia, since those pathogens are difficult to detect but are often found in combination with fecal coliform. Particularly, health authorities look for *Escherichia coli* (*E. coli*) in water, which is an indicator of fecal contamination and potential disease.

Bacteria is counted in "Colony Forming Units" per 100 millilitres of water (CFU/100mL). BC health allowance for drinking water is less than 2 CFU/100ml for "Total Coliform" and less-than 1 (< 1) for fecal coliform. If the water is disinfected, the allowance is 10CFU, and if the water is treated, 100CFU. The allowance for swimming water is less than 200 CFU/100ml for "Total Coliform."

The early tests (Zwickle, Croda, 1991-96), showed a distinct change from low or zero bacteria counts in the spring, to higher bacteria counts in the summer and autumn. In the fall of 1993 and '94, in both Hague and Gunflint, these tests found Total Coliform significantly higher than the health allowance for untreated drinking water, and the presence of fecal coliform, suggesting possible human septic and livestock contamination. In the summer and fall of 1996, these tests confirmed high counts of

Total Coliform, and the presence of fecal coliform, again above the health allowance for untreated drinking water.

The highest counts were found along the west shore of Gunflint Lake at the outflow of Linnaea Creek, and along the north shore of Hague Lake, from the foot of Austin Drive, along the sandy beach, to the foot of Christensen Road. The Croda-Zwickle report in 1995 stated: "Of 6 organisms identified, 5 indicated either sewage contamination or are potential human pathogens."

In 2003, the Regional District of Comox-Strathcona commissioned the report "Water Quality Study and Potability Analysis: Hague and Gunflint Lakes," written by Graeme Faris and Russ Hotsenpiller. They found the presence of fecal coliform in 50-of-129 samples from Hague Lake and in 51 of 79 samples from Gunflint Lake. Hague Lake showed significantly less fecal coliform during the winter months, but Gunflint samples showed positive coliform counts at all locations throughout the year. The north end of Gunflint, adjacent to the road and run-off locations showed high average values. Samples from August showed high coliform counts.

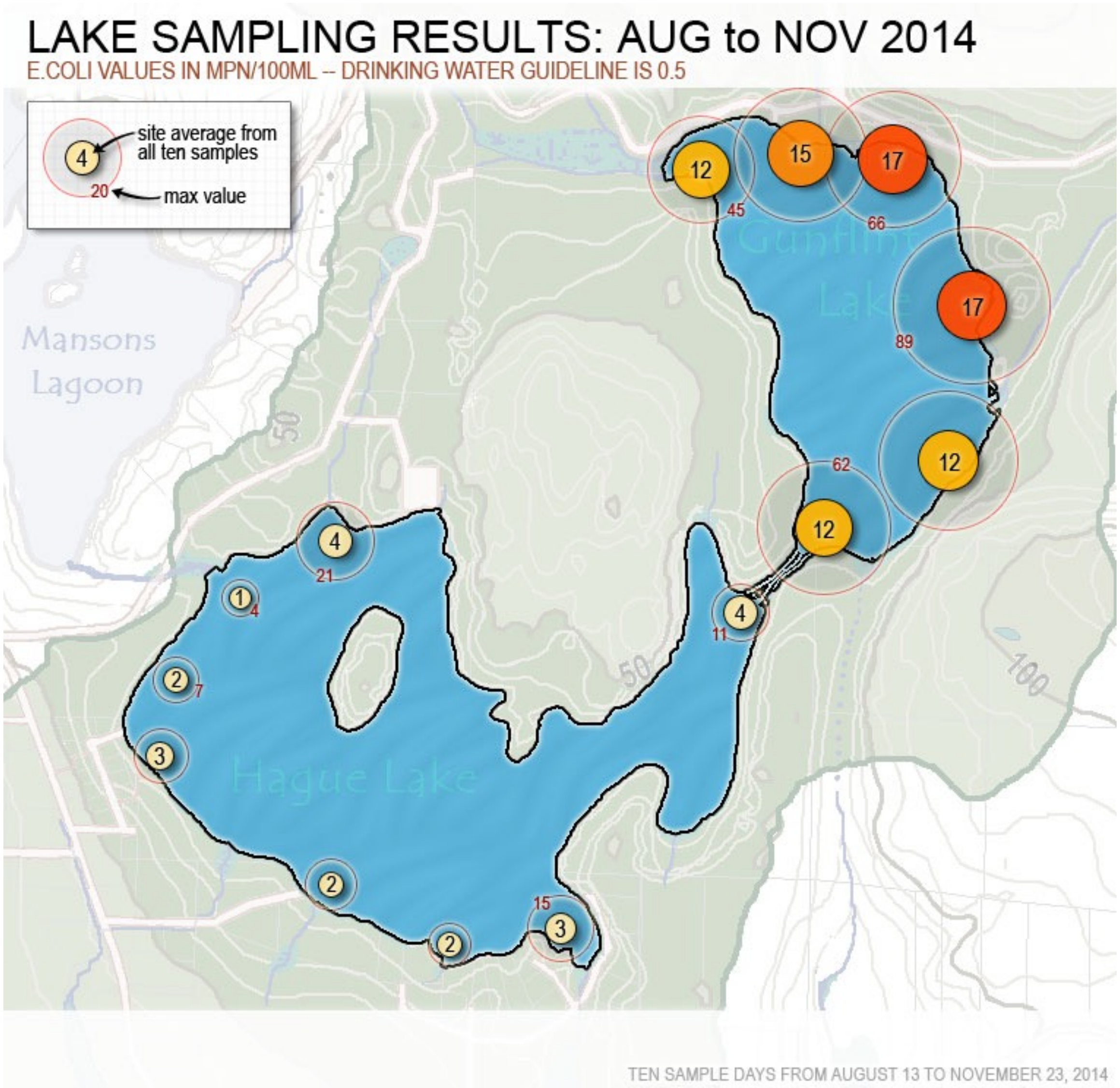
The report concluded that livestock contamination may be contributing to coliform counts and suggested that dye testing of individual septic fields could help determine the extent of septic contamination.

The 2014 sample testing (Shelling, Demers, BC MOE, FOCI) provided more specific data and suggested a significant increase in coliform bacteria from the 1990s samples and the 2003 samples. These test results used the more accurate Most Probable Number (MPN) method for assigning values to the samples. Ten sample sets taken from eight locations in Hague Lake and six locations in Gunflint, from August 13 to November 23, show elevated *E. coli* fecal coliform) levels in both lakes in all locations. Some locations appear more pronounced than others, but at some point during the summer, every site showed high levels.

The highest 2014 results came from the October 26 samples in both Hague and Gunflint lakes. Every site showed *E. coli* at levels exceeding minimum health standards for untreated, non-disinfected drinking water. Recall that the minimum allowance for untreated drinking water is less-than-1 CFU/100mL. The lowest result among the October 26 samples was 4.2 CFU/100mL; the average was over 37, and the highest result showed 69.7 CFU/100mL at two locations: West from the foot of Christensen Road in Hague Lake, and the creek inflow on the southeast shoreline of Gunflint Lake. All the Gunflint sample sites exhibited high E. coli counts, above 45 CFU/100mL.

High coliform counts may indicate a nearby source, but any source, anywhere in the watershed, can contribute to these counts. Water moves in the lakes, of course, and can collect in certain locations, especially in bays. The inflow from Linnaea Creek drains the watershed eastward past Easter Bluff to Mary Point Road, and north to Cowen Peak and Squirrel Cove Road. Likewise, the north shore of Hague Lake receives drainage all the way north to Lagoon Road and the wetlands by the Cortes Motel and Kwas Park trailhead. Any wildlife, livestock, or human septic in this drainage system could contribute to coliform counts at the outflow.

To track the species sources of this *E.coli* presence in the lake., the labs tested nine water samples, from the September 9, 2014 data collection in both lakes. This data set is still too small and preliminary to be definitive, but it does provide some useful information. One sample — from the north end of Hague Lake — confirmed a human source, six sites showed undetermined sources that could be human, three sites in Gunflint confirmed livestock, and one site confirmed domestic pet *E. coli*. Other sources included bear and gull, which seems reasonable, and "Elk," which does not appear likely and may be mis-identified. Without more source data, we cannot yet determine the extent of human *E.coli* in the lakes, but the samples confirm some sources from human septic, domestic animals, and livestock. More source testing should be a long-term priority.



E. coli bacteria test results, averaged from ten testing days between August 13 and November 23, 2014. The highest readings appear in Gunflint Lake at the inflow from creek-drained watersheds, as would be expected. The bacteria levels are lower toward the outflow at the North End of Hague Lake. These tests tracked source and confirmed that bacteria enters Hague and Gunflint lakes from wildlife, livestock, pet, and human sources. See "Recommendations" at the end of this report. Map by Barry Saxifrage, 2016.

These results, the presence of *E. coli* fecal bacteria in the lakes, are cause for serious concern and community-wide action, beginning with good management of septic systems and livestock run-off. It is important, for example, to drain animal pens around the perimeter and to store livestock manure in a location that does not allow the nutrients to seep into the ground and water table.

Cutthroat Trout

The local Cutthroat trout, related to ocean-going salmon, were left behind in freshwater lakes by receding sea levels, millennia ago. The trout require specific oxygen levels and water temperatures, and suitable environments for eggs and fry to develop. The cutthroat trout in our lakes require the following temperatures for successful reproduction:

Spawning: 9 - 12 °C
Incubation: 9 - 12 °C
Rearing: 7 - 16 °C

In both lakes, summer surface temperatures are outside the optimum range for cutthroat trout rearing, reaching 23°C, dropping into the optimum range at 16°C below six meters depth. In the fall and spring, the trout will find comfortable temperatures nearer the surface. Since Hague Lake is shallower than Gunflint (12m vs. 19m) it takes less wind to mix the lake water in Hague, and it becomes uniform earlier in the the fall.

(*Hague, Gunflint lake report, FOCI, Weyler, 2017 .. 14*)

The trout become stressed when oxygen falls below five milligrams per liter (5 mg/L), and these oxygen levels have to be maintained at the depths that also have the optimum temperature. Trout tend to prefer the cooler temperatures near the lake bottom, but sometimes during the year, especially in a high-productivity lake, oxygen levels can drop too low at these depths.

Cutthroat trout require specific temperature and oxygen range to reproduce and thrive. (Photograph by Fish Eye Guy)

In recent years, oxygen levels appear sufficient in the optimum temperature zones for Cutthroat trout. However, during a large algae die-off, oxygen is depleted and the fish can experience oxygen depletion stress. Furthermore, decomposing algae will fall to the bottom and can suffocate fish eggs.

Decomposing algae blooms can also choke off other life forms including feed for the larger fish. The cutthroat trout population appears to have suffered from the recent blooms. In the spring of 2014, residents witnessed an unusual number of dead fry and a reduction of active trout during morning and evening feeding periods. Fishers have reported unhealthy fish marked with sores, and less fish caught. Some local fishers have stopped fishing trout in these lakes to give them a chance to recover. In the spring of 2017, residents have reports slightly higher numbers of trout hitting the surface at feeding times.

6. Taking action

Although all lakes have natural sources of nutrients and bacteria, we have clear evidence that our own community sources — septic, livestock, pets, fertilizers, soaps, land use changes, and other human impacts — contribute both nutrients and bacteria to the lakes. The nutrients threaten to hasten eutrophication, and push the lakes toward swamp conditions. The bacteria threaten human health, recreation, and drinking water. Action by our community appears necessary to keep these lakes healthy.

Land use: The 2015 BC Ministry of Environment report, “Water Quality Monitoring Program, Hague and Gunflint Lakes, 2014-15,” urges the community to consider that roadways, parking lots, driveways, and other disturbances to the land and water-flow can decrease the watershed’s permeability, greatly diminishing its natural capacity to filter runoff or absorb nutrients and bacteria before they reach our lake. Our Hague-Gunflint watershed retains much of its ecological integrity, but every road or driveway cut into the land diminishes that integrity, and may increase runoff into the lake.

Land use changes along the lakeshore — residential clearing, docks, boat launches, and so forth — can reduce the nutrient and bacteria filtering of the natural lakeside plants. Lakeside residents and help by replanting disturbed shoreline with local, natural plants. Some residents have begun planting cattails, which are good for consuming nutrients.

(*Hague, Gunflint lake report, FOCI, Weyler, 2017 .. 15*)

Lakeside restoration on Lake Winnipeg, using cattails. A cleared lakefront can increase the runoff of nutrients and bacteria, and should be replanted with native lakeshore species. Cattails take up nutrients well. (Photograph from Environment Canada).

Agriculture, Logging, Land clearing: Erosion from land cleared for agriculture, logging, or other purpose can contribute to the nitrogen and phosphate load in the lakes. Agriculture, including livestock, grain production, and general farming can alter water flow and increase nutrients, toxins, or bacteria into the lake. All land clearing should include necessary ditching, drainage fields, and restoration of water flow and lost vegetation.

Nitrogen fertilizers are a particularly common source of nitrogen nutrients to the lake. Even organic fertilizers and manure can contribute these nutrients, so all fertilizers should be used sparingly. Runoff from farming, gardening, logging, and house clearing, can increase the rate of eutrophication and algae growth in the lakes. (See more details below in "Recommendations.")

Septic: Properly installed and operating septic systems with drainage fields will effectively treat human waste and grey water. However, The Ministry of Environment report warns that "Failure of onsite septic systems can cause significant nutrient and pathogenic waste to enter the water body and can be dangerous to human and animal health." Nutrients from septic will increase the extent of algae blooms.

The lakes will clearly benefit if every household in the watershed takes some responsibility to ensure that septic systems are functioning properly and that livestock and household pets are not adding nutrients or bacteria to the lakes. Look for particularly rich, damp areas above your drainage field, and dry areas. If these exist, your system is likely clogged where the dryer areas begin. Even without visible signs, a septic system can be partially clogged, causing extra runoff in some areas in which the soil and plants are not able to take up the nutrient load.

Biological remediation

"During bioremediation, microbes utilize chemical contaminants in the soil as an energy source and, through oxidation-reduction reactions, metabolize the target contaminant into useable energy for microbes."

Montana State University, "Bioremediation of Contaminated Soil."

From the data and reports, we see that the two most urgent issues facing our lakes are the added load of bacteria and nutrients. Toxic wastes are less obvious now, but also pose a risk to the lakes. Actions elsewhere show that all three of these threats — bacteria, nutrients, and toxins — can be successfully mitigated with community action, including with natural, organic, biological methods, generally known as "bio-remediation."

Bioremediation techniques typically use naturally occurring microbes (bacteria, fungi) and plants to remove or metabolize pollutants, to clean and restore contaminated soil, groundwater, or lakes. Bioremediation systems encourage the growth of certain organisms that consume contaminants, take up nutrients, treat water for toxins, and in some cases can remove industrial chemicals, petroleum products, and pesticides. Bioremediation occurs naturally in healthy ecosystems, and can be enhanced by design.

Some public systems treat septic and toxic effluent with bioremediation technologies such as adding oxygen and biological stimulation of natural purifying plants. Organic-nitrogen can be converted to molecules such as nitrate (NO_3) that are less harmful and will dissipate naturally. Some complex systems add industrial chemicals to remove toxins. Purely organic systems include plant buffers and biofilters using microorganisms. Certain microbes work in symbiosis with the plants help the soils capture phosphorus, nitrogen, and other pollutants.

Smart farmers and communities have used simple bioremediation for millennia. Even simple composting is a form of bioremediation that can kill unwanted bacteria or pathogens in soils. Some microbes can be added to soils or water to enhance the natural microbe's ability to break down contaminants, consume, digest, or neutralize contaminants.

Some compounds — certain heavy metals, such as cadmium or lead, for example — resist bioremediation. However, some recent studies have found that fish bone and bone char can remove small amounts of lead, cadmium, copper, and zinc from soils.

The simplest form of bioremediation for our lakes would be to replant disturbed shoreline in native species, to help take up the nutrient load from the human community.

Living machines

Some examples of bioremediation are provided by the work of Canadian, Dr. John Todd, a biologist who designs ecological remediation systems that purify water and soils and enhance food production. In the 1970s, Todd joined Woods Hole Oceanographic Institution and later founded the New Alchemy Institute to research ecological design, creating what he calls "Living Machines."

On Moskito Island in the Virgin Islands, Todd installed a biological wastewater treatment system designed to treat domestic sewage. The system is terraced on a steep hillside, using solar heat, gravity, and ecological systems to treat nutrients found in waste water. The nutrients are used as food to fuel the growth of plants, animals, bacteria and fungi throughout the treatment system.

In Fuzhou, China, the Baima Canal had become a toxic, eutrophic swamp with extreme odour and contamination created by 5 million gallons per week of untreated domestic sewage. Todd installed a bioremediation system to treat wastewater and sewage through a network of canals. A similar system he installed at Corkscrew Swamp in the US purifies public waste water and recycles 90 percent of the water back into a local park facility. All of this is achieved with natural living organisms.

Floating Vegetated Wetlands

Buoyant structures planted with aquatic vegetation, such that roots feed directly from the water, can take up nutrients and help prevent algal blooms. The plants compete directly with algae for light and nutrients, and the roots provide a biological haven for the development of biofilms that contain diverse communities of microorganisms, which help to clean the water of nutrients and contaminants. The result is a "concentrated wetland" effect. Evidence shows that nitrate, phosphorus, ammonia, and suspended solids can be removed. Aquatic oxygen levels can be increased.

Floating wetlands are commonly anchored to the shoreline or lake bottom. The growth media may include coconut fibre, jute, or synthetic mats with soil and sand. Commercial mats are available. The mats are planted with indigenous aquatic perennials that thrive with wet roots. Once planted, the mats are maintained by periodically trimming shoots and root mass to improve longevity and buoyancy. Wildfowl may occupy the mats, so anti-grazing protection may be necessary. The floating wetlands can stay in water year round, since freezing and thawing cycles do not harm the plants. Further research would be needed to assess the potential effectiveness of using for local lakes. It may be possible to suspend mats close to potential pollution sources.

Cattails:

Plant species, such as Canary grass (*Phalaris arundinacea*), common reed (*Phragmites australis*), and common cattail (*Typha latifolia*) produce sugar-like compounds that move through the roots into the rhizosphere, soil near the roots, where microorganisms and bacteria feed on plant cells, proteins, and sugars. In these rhizosphere zones, protozoa and nematodes feed on the bacteria, and fungi interact with plant roots to enhance nutrient collection or disease resistence. The compounds released amplify denitrification, nitrate reduction, that help the plants take up nitrates.

Common cattail, native to our lakes, is highly prized for its nutrient capture and water quality benefits. Some Cortes residents have already begun planting native cattail around the lake wherever the foliage has been disturbed.

At Lake Winnipeg in Manitoba, for example, suffered from high levels of phosphorus loading from the surrounding community, causing severe algae blooms and eutrophication. Researchers planted cattail to reduce nutrient flows, and are now harvesting cattail as a heating fuel, further increasing the nutrient removal, since the plants are not left on the lakeshore to eventually decompose. Young cattail reaches maturity in less than 90 days, and late summer/early fall harvests yield high levels of nitrogen and phosphorus locked into the plant tissue. As an added benefit, the cattails provide a biofuel that does not require normal agricultural land, with an energy output similar to commercial wood pellets. About 88% of total phosphorus is recovered in ash following combustion. This phosphorus can eventually be used as a farm or garden fertilizer.

Fungi: **Myco-remediation**

Mycorrhizae fungi support plants by extending the root structure to bring water and nutrients from greater distance, sometimes from over 20 meters away, helping plants survive droughts and thrive in marginal soils. Certain plant root systems will more effectively explore a larger volume of soil with mycorrhizae helping increase the volume of soil that plant roots explore. Fungi can also support biological remediation of pollutants.

Myco-remediation utilizes the natural symbiotic characteristics of fungi to take up bacteria, nutrients, and heavy metals and toxins. In the ecosystem, fungi facilitate decomposition, pest control, and nutrient absorption into plants, including trees. Mycelium can secrete enzymes and acids that break down lignin and cellulose in plant fibre, while building organic molecules that are structurally similar to some organic pollutants. Myco-remediation matches particular fungal species with target pollutants. For example, wood-degrading fungi are effective in breaking down petroleum compounds and chlorinated pesticides. The Ecuadorian fungus *Pestalotiopsis* can consume Polyurethane.

In Mason County, Washington, US, mycologist Paul Stamets used mushrooms to filter grey-water, capturing contaminants. He placed a row of burlap sacks filled with oyster mushrooms, at the front of the drainage area to capture petroleum products and E. coli. If there is mercury in a water table, the fungi Turkey tail can be used to bind mercury with selenium, forming a non-toxic compound.

To capture phosphates, nitrogen, and bacteria around the Cortes Island lakes, Stamets recommended Garden Giant mushrooms (*Stropharia rugosoannulata*). Stamets donated the mycelium spawn and consulted with FOCI. Cortes Island resident Giorgio Giovinazzo coordinated the project and Linnaea Farm Society provided a section of land along a drainage ditch to grow out the mycelium and begin the first experiment.

This particular stream drains a large field, where horses and cattle craze, providing a good site for remediation opportunities. The Linnaea land stewards helped plan, install, and maintain the mushroom bed. In October 2014, Giovinazzo and a team of volunteers collected alder chips, soaked them for two weeks to eliminate competing mycelium, drained, and inoculated with the mycelium spawn. The containers of inoculated chips were stored at Linnaea Farm for winter grow-out for 5 months. Infections were identified and removed during this period.

(*Hague, Gunflint lake report, FOCI, Weyler, 2017 .. 18*)

Garden giant mushroom growing from Stropharia rugoso-annulata mycelium inoculated into alder chips and installed at Linnaea Farm. FOCI and Linnaea volunteers will propagate the mycelium for additional myco-remediation sites.

In the spring of 2015, the inoculated chips were mixed with more chips and spread into mushroom patches, one patch as a myco-filter in the drainage ditch, and one higher on the upland as a grow-out site for future propagation. In the fall of 2015, the sites produced the first Garden Giant mushrooms from the mycelium.

The myco-filter in the ditch partially washed away, so we learned that we have to create some method of containing the chips and mycelium, either with a burlap bag as Stamets has demonstrated, or with some other kind of restraining fence.

These sites could be used to grow and propagate mycelium. There is potential to make myco-filters available to install on private land, below septic or livestock fields, throughout the Hague-Gunflint watershed. Planting mycelium in buffer zones around streams can also work, since the mycelium remains shallow in the soil and combines symbiotically with trees, shrubs, grasses, and debris fall-out to create a mycologically rich riparian zone. These rich riparian zones are cooler, filtering run-off from any groundwater source, attract insects which lay larvae (grub for fish), and attract birds. Once the riparian zones achieve a plateau of complexity, they become self-sustaining.

The right approach:

The visiting biologists in 2014-15 — Eric Demers and Rosie Barlak — confirmed that the Cortes community was responding early and correctly to these risks. Dr. Demers advised the community to continue with our remedies – septic upgrades, bio-filtering, eliminate phosphate cleaners, replant cleared lake-front, convert outhouses, and so forth. Both Barlak and Demers believe that we can stabilize the algae and bacteria blooms, and even reverse the trend with careful water quality management.

The lake biologists told us that they have visited lakes in British Columbia that were much farther along in the process of eutrophication, with larger annual algae growth and depleted oxygen. They have indicated to our community that we are approaching this challenge correctly, by acting early, monitoring the lakes, informing the public about how we all can contribute, and then taking the important helpful actions.

We have time to respond sensibly, without panic. We will continue the monitoring and testing over the coming years, and watch for the algae blooms in the spring. Over several years, we will gain a good picture of the lake system's health. Our community will be wise to make every effort to reduce nutrient flow into the lakes. Recommendations for action, based on the Minister of Environment Report, earlier studies, and ongoing monitoring follow below.

Hague Lake from the west, over Mansons Lagoon: The Hague-Gunflint lake system is fed from a 13.6 km^2 watershed, stretching north to Cowen Peak and Squirrel Cove Road, east past Easter Bluff to Mary Point Road, and northwest to Lagoon Road and the wetlands near the Kwas Park trailhead. The lakes are connected by a narrow channel, and they empty eastward via underground channels and lowlands toward Cortes Bay and westward through a stream into Mansons Lagoon.

Recommendations for Household and Community Actions

The short, high-priority list (see details and more tips below):

1. **Septic**: Inspect, pump, and maintain your septic system
2. **Livestock**: manage livestock, manure, and domestic pets
3. **Fertilizer**: Avoid nitrogen fertilizers, and use all fertilizer and manure sparingly
4. **Lakeshore**: Replant disturbed shoreline, plant water plants along shoreline
5. **Cleaners**: Eliminate phosphate soaps

We can reverse the trend of increasing bacteria and algae blooms in our lakes, the risk of extreme eutrophication or over-productivity that can convert lakes to swamp-like conditions.

We cannot necessarily control or alter the natural influences on the lake ecology: Climate change, wildlife, or internal nutrient loading from decomposition in the lakes. However, the two primary challenges — bacteria and algae blooms — have human community influences that we can alter. This is where we can take action.

Bacteria and the nutrients that feed algae blooms arrive in the lake from ecosystem and human community sources. There are two sets of actions we can take:

1. Identify human community sources and slow or stop those pollutant flows.
2. Repair, restore, and enhance the ecosystem to absorb pollutants that we cannot stop.

Here are the actions we can take that will contribute to preserving the health of Hague and Gunflint Lakes:

1. Research and monitoring

- **Monitor:** FOCI is committed to working with the community to continue lake monitoring, sampling, and testing programs to collect, collate, and analyze data. We will monitor temperature, oxygen, water clarity, biodiversity, fecal coliform levels, and nutrient levels (nitrate and phosphate) in the lakes. Our monitoring should help identify hotspots; likely sources of bacteria, nitrates, and phosphate; and allow us to measure change over time. Dye tests for individual septic systems can be done with help from the Regional District, if desired.

- **Volunteer**: You can help with FOCI's Water Monitoring Project**.** Volunteer or make a donation. All donations will go directly to water sampling and lab analysis. We need to raise $5,000 to cover these costs for one year. Cheques can be mailed to: PO Box 278, Manson's Landing, BC, V0P 1K0. To volunteer, or if you have relevant observations, research, experience, or expertise, please contact Helen at: friendsofcortes@gmail.com or 935-0087.

2. **Septic:**

- **Inspect** your septic system annually and pump it every 2-5 years. This is far cheaper than cleaning out clogged pipes or rebuilding a drain field.

- **Maintain** your septic system; learn how you can keep it operating properly. All septic systems require maintenance. Upgrade your system if possible, and specifically, ensure that your septic lines are clear and that the drainage field is not clogged. Wet and dry areas over your septic field indicate clogging.

- **Location**: Keep septic fields well back from the lakeshore, and maximize foliage between septic field and lake.

- **Outhouses**: Convert raw outhouses to composting systems, and move any outhouse well back from the lake, 20 meters (60ft), or more. Maintain foliage between outhouse and lake. The outhouse pit bottom should be two meters above the water table or bedrock, and pit sides reinforced with lumber, stone, or metal, surrounded by good soil that is raised and mounded to aid run-off. A two-pit, alternating compost system helps, and a fully contained composting system is best.

- **Dye tests**: These tests can identify outflow reaching the lakes from individual systems, and could be carried out by the Regional District.

- **Community funding**: FOCI and the watershed community could apply for funding to help test and upgrade septic systems, and seek other support from the Regional District.

3. **Livestock and pets**

- **Locate** farm animals far from the lakeside.

- **Divert** water flow away from animal pens, and treat outgoing effluent. Divert runoff away from streams that empty into the lake; send water through drainage fields.

- **Manure**: Construct adequate manure storage and composting bins. Leaching manure piles are sources of nitrates and bacteria.

- **Fencing**: Install barriers to prevent livestock from grazing on stream banks and lakeshore. If livestock cross steams or tributaries, provide gravel or other hard access ground. Provide water troughs to avoid livestock drinking from streams.

- **Pets**: Pick up after your domestic pets, compost manure.

4. **Gardens, Agriculture, Land Use**

- **Fertilizers**: Avoid inorganic fertilizers, which typically contain nitrates. Even organic manures, in large quantities, can leach nitrates into the water table. Let manure compost completely before applying on farmland, gardens, or lawns. Avoid fertilizers during heavy rain season, water lightly at first.

- **Compost** yard and food waste, and use in garden rather than commercial fertilizer.

- **Pesticides**: Avoid toxic pesticides; use natural insecticides, such as diatomaceous earth. Prune infested vegetation rather than use pesticides.

- **Paving**: Use paving stones, with drainage, rather than solid pavement.
- **Manure**: Use adequate storage, isolated from runoff. Do not spread manure in wet weather, on frozen ground, in low areas prone to flooding, or within 5 metres of drain ditches or streams.

5. **Shoreline**

- **Crops**: Do not plant crops right up to the lakeshore.
- **Preserve vegetation**: Avoid disturbing the shoreline, replant after any disturbance, keep foliage thick along shorelines, and between households and shorelines. Plants take up the nutrients that feed algae blooms.
- **Plant**: Water plants, cattails, and other native vegetation along the shoreline, or leave areas undisturbed and allow them to revegetate naturally.
- **Docks**: If you have a dock on the lake, do not allow the dock to interfere with natural vegetation; design docks to allow maximum shoreline vegetation.

6. **Household Waste**

- **Cleaners**: Avoid phosphate cleaners or detergents. Use **phosphate‑free** soaps and detergents which are readily available at island markets.
- **Chemicals**: Don't put toxic chemicals (paints, varnishes, thinners, waste oils, photographic solutions, or pesticides) down the drain. These toxins kill bacteria that work in your septic system, and they can leach into the lake.
- **Conserve water**: High water flow from homes washes more nutrients into the lakes. Limit water flow with low‑flow shower-heads, faucets, and toilets; limit flushing; use washing machines and dishwashers only when full, sparingly. A brick in the toilet means less water with each flush. Simple and helpful.

7. **Automobiles and Equipment**

- **Oils**: Don't let oil spill on the ground: Use a drop cloth when working, fix any oil leaks.
- **Recycle** used oil, antifreeze, and batteries
- **Cleaners**: Use phosphate-free, biodegradeable cleaners when washing a car or other equipment.

8. **Boats**

- **Cleaners**: Use phosphate-free, biodegradeable cleaners
- **Bilge pad**: Use absorbant bilge pads to soak up leaks or spills
- **Boat bottom**: When transferring boats into the lake, check for and remove aquatic plant fragments from boats and trailers. Particularly, Eurasian milfoil is an aggressive invasive plant species; be familiar with this plant, and do not let it transfer to our lakes.
- **Docks**: Do not use metal drums in docks; they rust, sink, and become pollutants. Use blue or pink, closed cell extruded polystyreme billets or washed plastic barrel floats; label them with the owners name and phone number in case they float away.

9. **Biological remediation**

- **Plant**: Planting shorelines with native vegetation, or protecting shorelines to regenerate naturally are simple actions that help. Create buffers between homes, roads, and the lake shoreline.

- **Biological systems treatment**: We are investigating "bio-remediation" systems that increase uptake of nutrients in the watershed before they reach the lake. You can help.

- **Mushroom beds**: Paul Stamets has donated a culture of Garden Giant (*Stropharia rugosoannulata*) mushroom mycelium, and we have established a bed at Linnaea Farm. We plan to investigate the feasibility of making myco-filters available for installation on private land.

- **Septic Fields**: Install septic bio-filtering fields

- **Biological lake treatments**: Other biological treatments exist to help stabilize the lake, including compost extracts, protozoan infusion, and bacteria. These methods do not solve the nutrient inflow, but help take up that inflow.

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Clu-in, EPA report: Citizen's guide to bio-remediation

Helping the Ecosystem through mushroom cultivation: mycoremediation, Paul Stamets, Fungi Perfecti

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More Information and resources on Friends of Cortes website: friendsofcortes.org/lakes

Experts consulted in this research:

Rosie Barlak, Environmental Impact Assessment Biologist, Ministry of Environment in Nanaimo

Dr. Elaine Ingham, microbiologist and expert in soil/water ecology, chief scientist at The Rodale Institute, and author of the USDA's Soil Biology Primer, colleague of Cortes Resident Caleb Summers

Caleb Summers: Agro-Ecological Microbiologist, Hague Lake watershed resident

Christian Gronau: Palaeontologist, geologist, biologist; Cortes resident: Mr. Gronau has helped identify the organisms we have observed.

Lauren Miller: Village Bay Lakes algae bloom report

Sabina Leader Mense: Eldron Consulting, Cortes resident, Cortes Island Water Resource Survey Report (2010)

George Sirk, naturalist, former Cortes Regional Director

Bristol Foster, former director of Provincial Ecological Reserves

Dr. Eric Demers, Professor, Biology Department at Vancouver Island University

Amanda Glickman, toxicology biologist

Paul Stamets, mycologist, founder of Fungi Perfecti

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