ENVIRONMENTAL EVOLUTION OF THE **FITCH BAY WATERSHED**

Final Report

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PROGRAM IN ENVIRONMENTAL MANAGEMENT AND CLIMATE CHANGE

SUMMARY

Key words: Fitch Bay, environmental evolution, Lake Memphremagog, cyanobacteria, eutrophication, land use, water quality, erosion, sedimentation, fish species, climate change

Fitch Bay is a central part of Lake Memphremagog in which environmental problems have long been identified. In the 2015-2020 action plan, created by Memphremagog Conservation Inc., one of the recommended follow-up methods entails the realization of a historical portrait of the area's natural heritage (MCI, 2015). The mandate for this project was taken up by a team students called MAP2 consultants, from both the *Université de Sherbrooke* and Bishop's University. Research was conducted over the semester, gathering information from countless sources. The present document is the final report for this project. It attempts to draw ties between past events and the current environmental situation of Fitch Bay.

Four fields of impacts were investigated: aquatic, living, social and territorial, The information was then assembled into a timeline. This technique permitted a greater appreciation of the Bay's evolution by linking several historical alterations to the current state of the Bay and its watershed. We found that most problems originate from causes other than what is seen in other parts of the country. Additional steps are suggested to improve our understanding of the region's evolution by applying more detailed analyses. This includes processes of core sampling for paleontological studies that would provide supplementary scientific results. These methods could be done over a longer period.

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INTRODUCTION

Ecosystems have always experienced changes, which influenced their evolution and led to their current structure. In Fitch Bay, human alterations have contributed to the degradation of this natural environment and its functions. The current situation is a cumulative result of the impacts caused by previous disturbances, of which most occurred over the last century.

Past studies conducted in this area have identified the environmental issues affecting it, and consequently, provided efficient solutions to protect its natural surroundings. However, this knowledge remains incomplete, as little was known about this area's past before now. A historical review is necessary to understand the development of the present problems and establish solutions to preserve its quality for the future.

From this perspective, the present report delineates the environmental evolution of the Fitch Bay watershed. The aim is to draw a historical portrait by integrating past events that modified the quality of the Bay with present challenges. To achieve this objective, we have developed an approach focused on the environmental issues identified in the Bay. The methodology provided was based on varied data that was collected, analyzed and linked in time. The study was conducted primarily in the central water body; however, some sections integrated available data for a much larger area.

First, the methodology is detailed, including a description of the studied area and the adopted approach and methods. The second section of this report presents the social evolution of the region and the timeline, the result of our research. The third part is dedicated to the land use evolution. The discussion of the connexions between past events and current environmental issues constitutes the fourth segment of the document. Finally, a fifth subdivision displays our considerations for the future of Fitch Bay.

1. RESEARCH PROCESS

This project establishing the environmental evolution of Fitch Bay is restricted to this region. In searching for information, we constructed a coherent, reliable, and replicable methodology that was utilized to obtain the most accurate facts available on past events. The following section defines the study area, historical research in environment, and the steps taken in this project.

1.1 Area Description

The project was conducted in the Fitch Bay watershed, draining into the west side of Lake Memphremagog. Several effluents bring water to the Bay: in the North by Bunker and Fitch watercourse, in the East by Gale, Bachelder, and Tompkin streams, and in the west by Lime Kiln watercourse. The water then drains southward Fitch Bay southeast and then northward towards the lake's outlet, Magog River. Stanstead Township, Ogden Municipality and Magog City govern the region.

While certain aspects of the present analysis extend outside this area, most of the impacts can be seen in the central Bay area. Therefore, we focused on Fitch Bay subwatershed (Fig. 1.1) with some additional information integrated from adjacent locations to provide a better understanding of the environmental evolution.

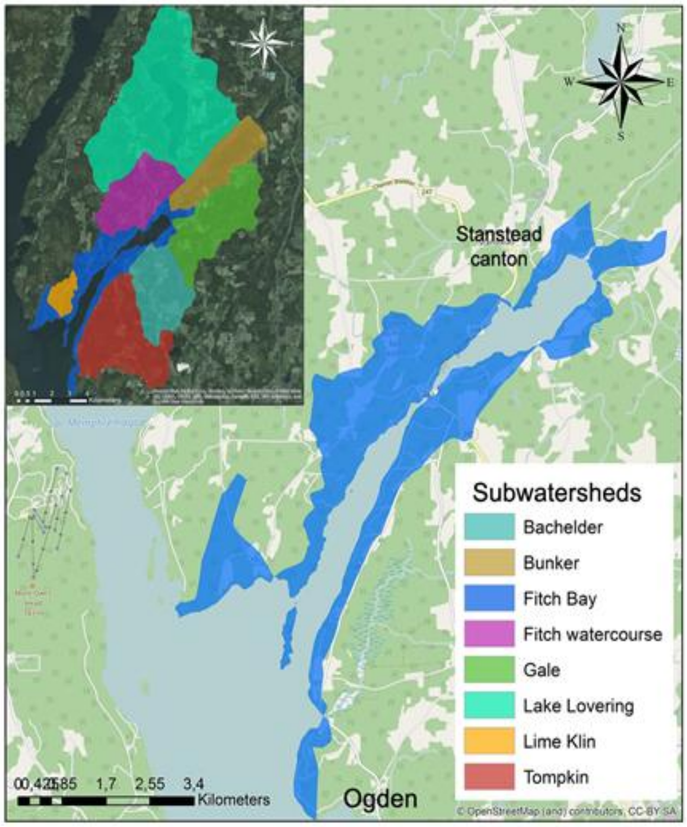


Figure 1.1: Map delineating the main study area (Source: MCI)
The study area covers a surface of 1472 hectares, dominated by forests. Agriculture and farming lands, in addition to residential areas, also occupy parts of the region.

1.2 Approach

To understand a territory's evolution, it is necessary to study the social and ecological changes as they often are the leading causes for environmental damage (Figure 1.2). In the social component, we found laws that affected the area, such as pesticides, population changes, land value, knowledge of the problems and the institutions monitoring them. The ecological section includes water quality, species variation, and land use changes. This information was found mainly in archives or can be obtained by scientific methods such as soil core analyses.

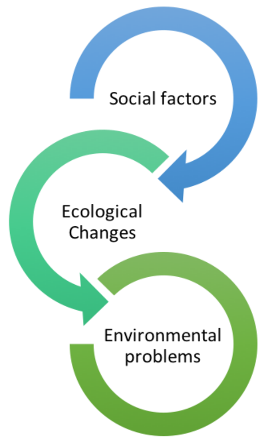


Figure 1.2: The steps of historical analyses. Adapted from Ali and al., 2017

1.3. Methods

The approach used for this project was developed to address the environmental issues listed in the report "Healthy Fitch Bay: From diagnosis to solution" published by MCI. Research was conducted on soil, water, microbiology, and socio-economic impacts. Considering the aim of our mandate, we looked for historical sources to assess the environmental evolution of the studied area. The information collected was diverse: governmental documents, scientific studies, historical societies, environmental reports, water and microbiological analysis, in addition to geographic files and aerial photographs. Our research also included both French and English documentation, considering the bilingual characteristics of the region. Information was collected mainly from secondary sources, but primary sources were also influential in providing additional evidence about the historical aspect.

Our methodology consisted of three main steps. First, all available data (qualitative and quantitative) were assembled separately for each area of interest. This step consisted of finding events that have possibly affected the environment of our area. Secondly, events found in the first step were Assembled into a timeline. Added to scientific research on the most important environmental issues of the Bay, the timeline shows the eventual connexions between events. These were traced back through time to allow a better interpretation of major key events that affected this environment in different periods.

Challenges faced during this project were mostly related to data availability and time constraints. The methodology described in this work (Figure1.3) can be applied in future studies on the Fitch Bay watershed to improve the appreciation of the environmental issues of that area.

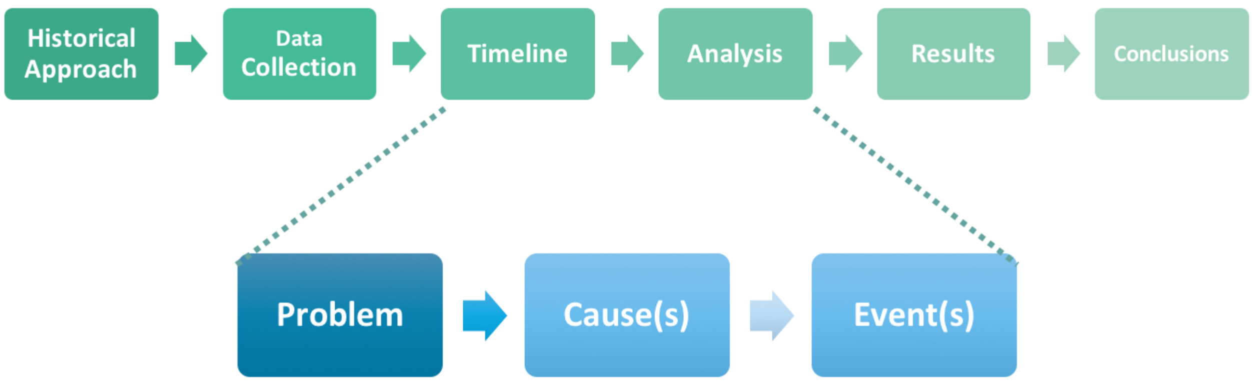


Figure 1.3: Methodological approach used in this project.
Recommendations were given based on the historical aspect of the Bay evaluated in this project. Our suggestions are oriented toward mitigating the impact of different factors on the Bay's watershed and a better comprehension of its environment.

2. FITCH BAY'S EVOLUTION

To understand how past events have influenced Fitch Bay and its environment, it was important to get a clear idea of the population's changes. A short history of social and economic development in the region highlights predominant occurrences. This project has put other happenings together to create the timeline presented in section 2.2. The idea was to create grounds for discussing links between these changes and the arrival of environmental challenges.

2.1. Social Development in the Region

Both Fitch Bay and the greater Stanstead Township were established in 1855 by American settlers looking for cheap lands to use for agricultural purposes. At that time, agriculture and forestry were the main sources of income in the area. The town quickly became known as the "poor French people's town" (Langlois, 2017), unlike Georgeville, which was predominantly English and easier to access. The American Civil War (1861-1865) brought a thriving forestry industry to the region but it disappeared almost as fast as it began, due to the secluded nature of Fitch Bay. This also explains why, to this day, there are minimal tourist activities, while the Eastern Townships is one of the most touristic regions in the province. In contrast, frequent cruise ferries used to cross Lake Memphremagog daily going from Newport (Vermont) to the Lantern Tavern in Georgeville. This activity ceased in 1953 due to the lack of business (Société d'Histoire de Magog, 2011).

After the construction of the Magog dam in 1888, waters submerged the Northwest part of the Bay. It then became a nursery for fish as well as a sure place to have something to eat for dinner. Fishing has never been industrial grade, due to the size and depth of Fitch Bay and its secluded location. The Fitch Bay Marina opened in 1985, welcoming 800-1000 boats a year, many for fishing trips to Owl's Head. To get an idea of the number of boats in the Bay, residents boats must be added to this number, which is considerable: Fitch Bay's maximal population in the summer nears 1700 individuals. In 2016 summer, 17 residents used wakeboats that generated oversized waves to practice water sports. (Pouillot, 2017; Orjikh, 2017).

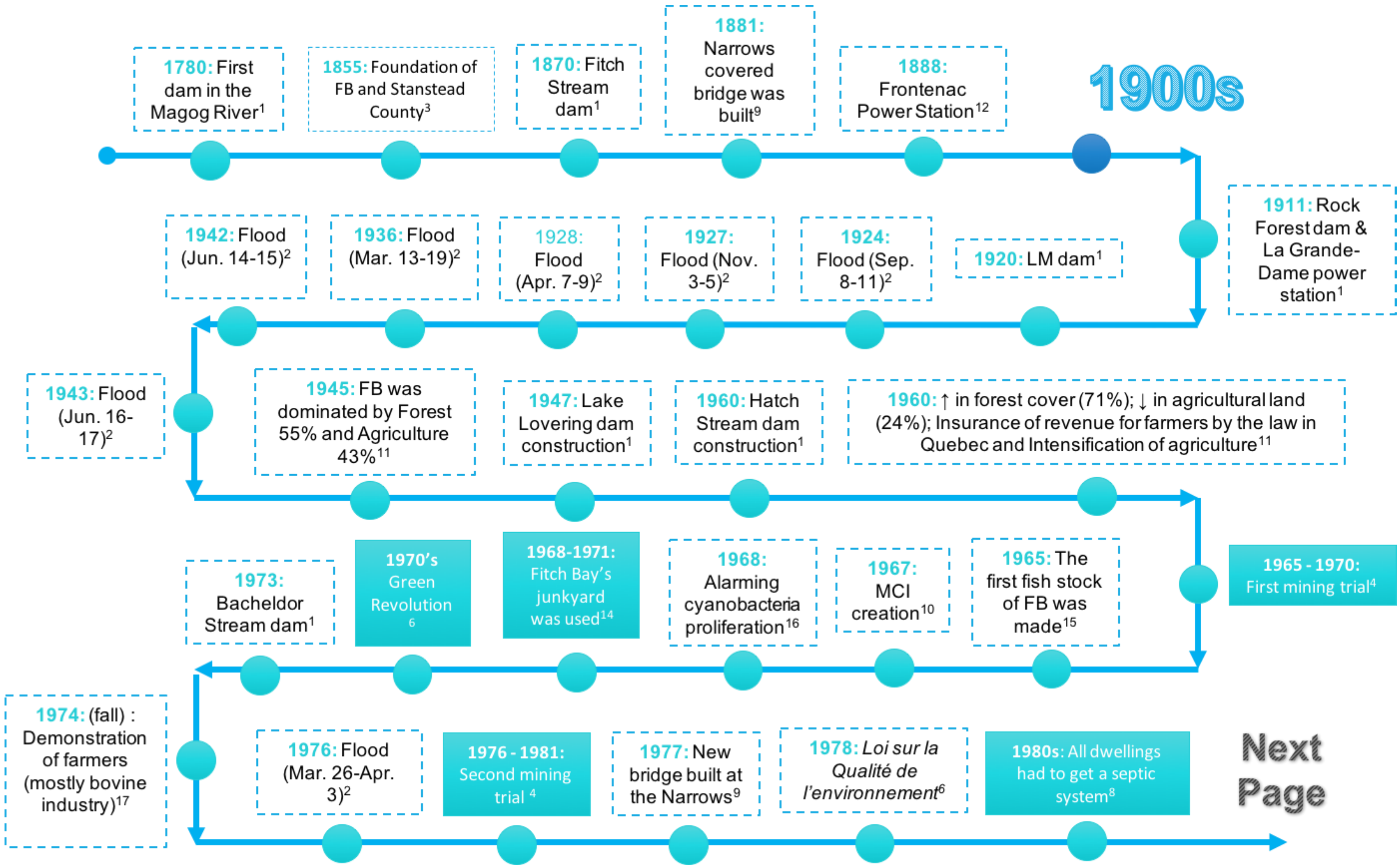
When the Industrial Revolution (1860-1950) reached Canada, urbanization grew and agricultural methods had to adapt to this new demand. The Green Revolution, which occurred after the Second World War, also brought changes in agricultural practices. By the 1970s, most of these innovations had been introduced to the area. They began to use fossil fuel dependent machinery, chemical pesticides, and synthetic fertilizers rich in phosphorus, which quickly became common practices. Farms expanded, thus those who could not keep up with the changes were forced to sell and relocate to the neighbouring cities such as Magog and Sherbrooke. The raising of livestock, the most popular exploitation in the Eastern Townships, dwindled in Fitch Bay after 1950 (Ruiz and Domon, 2005). Today, only a few pig and cattle farms remain, mostly around the Gale watercourse. There is also corn cultivated near the Bunker stream and several ornamental horticulturists (MCI, 2015).

Mining was considered as a possible prospect for Fitch Bay and its surrounding area. Copper and asbestos mines were operated in the 19th century with little success. Two sites extracting rhyolitic tuff and gabbro-diorite gravel were sporadically opened between 1965 and 1980. Additionally, a small gravel site served only during the summer of 1978. Studies show that despite its proximity to the Sherbrooke-Weedon mineral furrow, the region does not contain any interesting deposits for this industry (Römer, 1980). It does not benefit from the large quarry pit located in Ogden, which supplied granite for many important buildings in the region: Saint Benoit du Lac Abbey and even the Sun Life building in Montreal (Ogden Municipality, 2017).

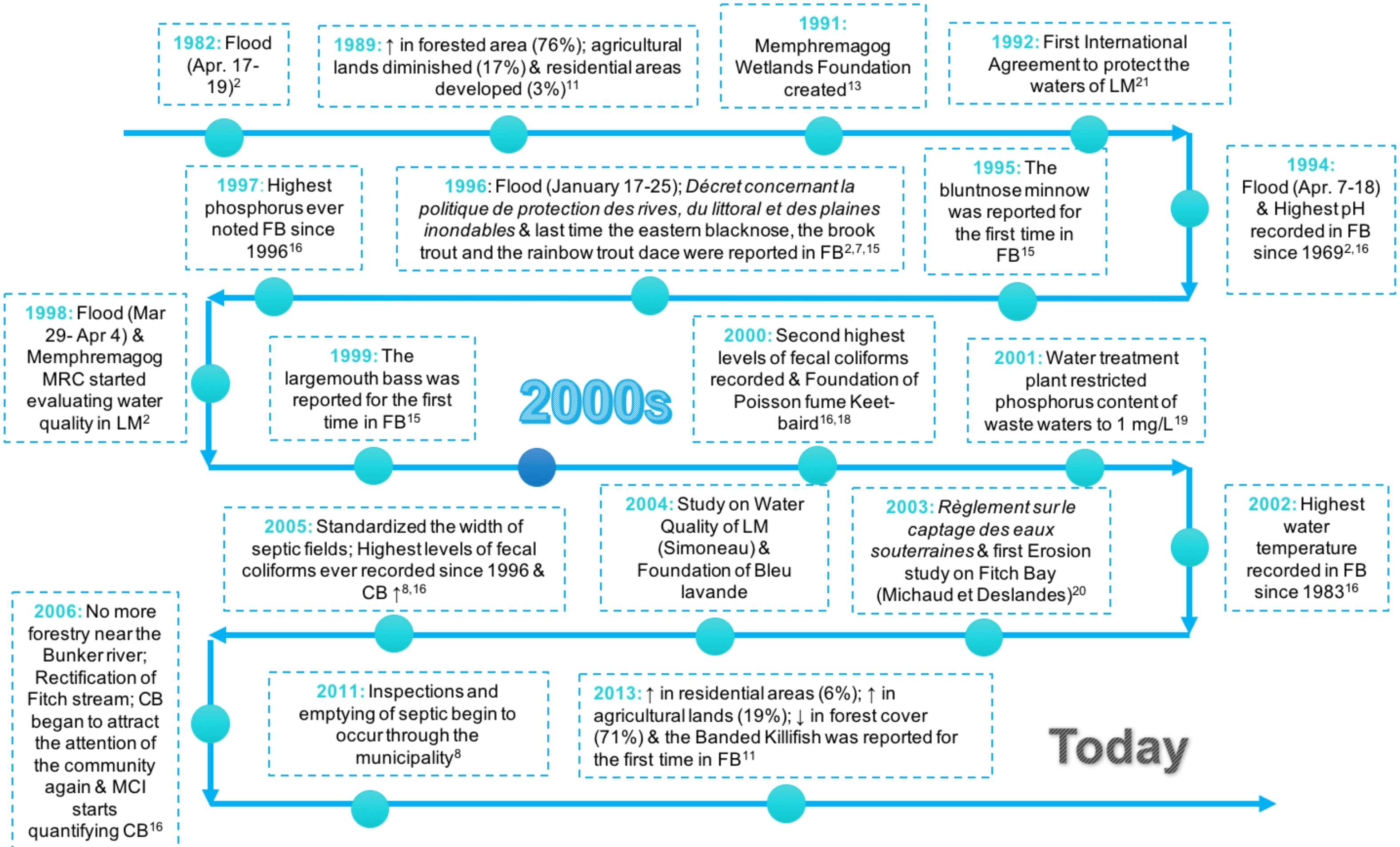
More recently, another touristic interest has been bringing people to the Bay. In 2004, *Bleu Lavande* quickly became the economic focus of the area, despite a few difficult years. The first lavender farm in Northern America sells its products across Canada and insists on growing them without the use of chemical pesticides. Since 2009, they offer spa treatments and tours of the farm during the summer. (Bleu Lavande, 2017)

Over the past century, Fitch Bay has known slow economic growth. The County's average economic vitality indicator was -2,59687 in 2014, ranking it 713 overall out of 1476 municipalities in Quebec (MAMROT, 2014). Property evaluations change dramatically from one year to the next, but the price per square meter in Stanstead Township is still greatly inferior to that of Lake Memphremagog. (MAMROT, 2016; Pouillot, 2017)

2.2 Timeline



[1]Fouquet, 2017; [2]Saint-Laurent & Hähni, 2008; [3]Bourassa, 2012; [4]Römer, 1980; [5]Ruiz and Domon, 2005; [6]RLRQ c Q-2; [7]L.R.Q., c. Q-2; [8]Vanasse, 2017; [9]Ponts couverts du Québec, 2015; [10]MCI, 2017; [11]Université de Sherbrooke Géomatheque, 1940, 1960, 1989 and 2013; [12]Fouquet, 2017;



Abbreviations: Cyanobacteria Blooms **(CB)**, Fitch Bay **(FB)**, Lake Memphremagog **(LM)**, and Memphremagog conservation inc **(MCI)**.
The events in the light blue boxes lasted more than a year.

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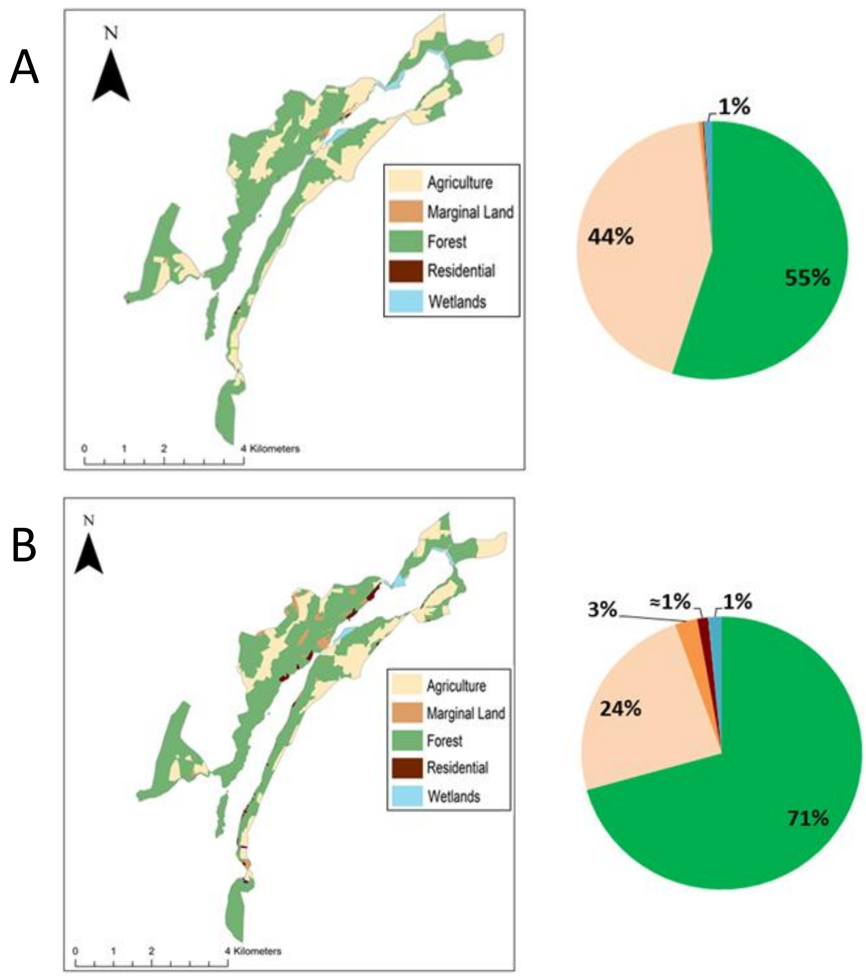
[13]Canton de Stanstead, 2013; [14]Gagnon, 2016; [15]MCI,2014; [16]MDDELCC, 2008, Environment Canada and 2006 MCI, 2015; [17]UPA, n.d.; [18]Keet-Baird, n.d; [19]Conton de Stanstead, 2015; [20]RLRQ cQ2, r6; [21]GOQ 2 4246, 1992

3. LAND USE EVOLUTION

Land usage in Fitch Bay has changed over time, from the days dominated by agriculture and grain production to the present based on tourism and nautical activities. Recognizing the changes in land use is crucial in deducing the issues affecting the Bay, given the close interaction between soil and water. Aerial photographs were handled to identify the different categories of land use. The images were then digitised with ArcGIS. Moreover, surface calculations were made (Figure 3.1). To maximise efficiency, a series of photographs with minimal cloud cover was chosen with a 15-20-year gap. Images were selected from 1945, 1960, 1989 and 2013 (*Géomathèque* of the *Université de Sherbrooke,* 1945; 1960; 1989; 2013). In this way, a general idea of land use changes allows for a better consideration of historical aspects in the area.



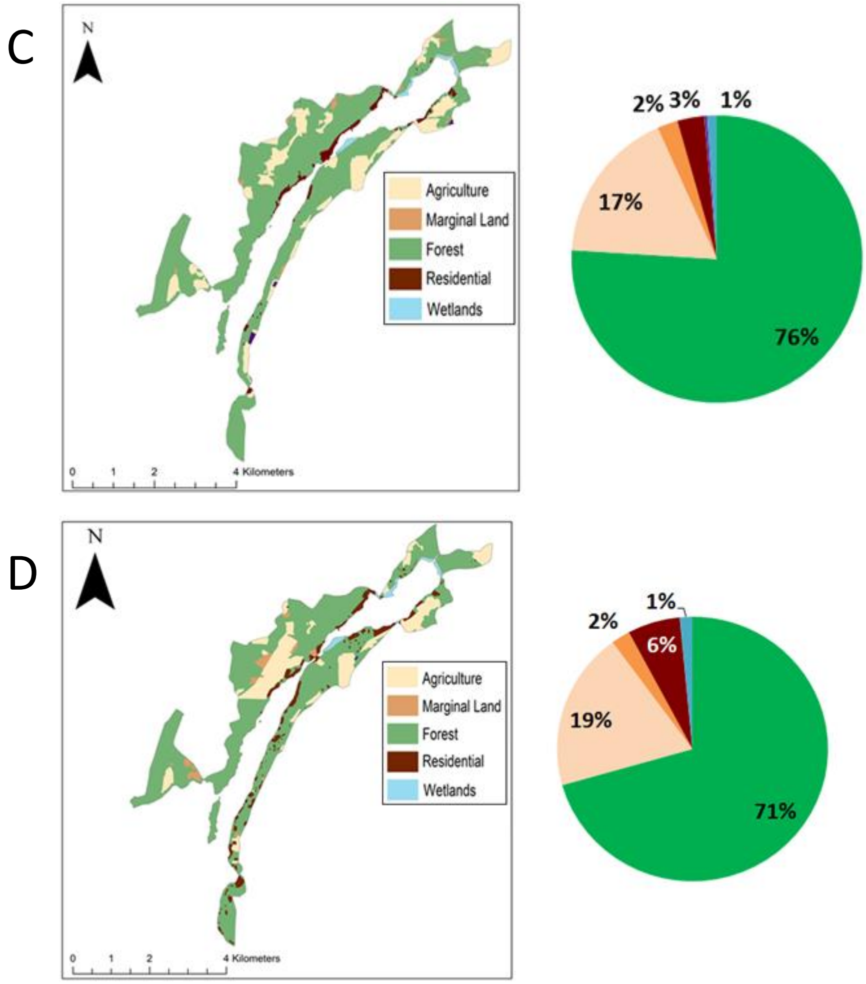


Figure 3.*1: Land use maps and pie charts showing the evolution of space occupied by agriculture, wild land, forests, residential, and wetlands.* *Images correspond to 1945 (a), 1960 (b), 1989 (c), and 2013 (d).*

Fitch Bay is located on what were mainly forests with a few wetlands. The Northwest part of the bay used to be a marsh that was submerged when the first dam was built, creating the Bay that distinguishes the region today. By 1945, nearly 44% of this land had been converted for agriculture, mainly north of the Narrows, leaving only 55% of forests untouched. Some years before 1960, many small farms were forgotten, becoming wild land and eventually returning to a forested state. Agriculture was reduced to a mere 24%, dropping further to 17% by 1989. At this time, there was also a 2% increase in residential use on the Bay's northern shore. Residential occupancies doubled by 2013, now representing a total of 6% of the landscape. Populated regions extended beyond the shoreline to previously forested areas east of the Bay. Some were built in proximity to wetlands threatening the integrity of these fragile ecosystems. This urban sprawl is commonly labeled as the starting point of several environmental problems in Fitch Bay.

4. DISCUSSION

Environmental problems have an initial cause often created or worsened by humans. In the previous sections, the major events that occurred in and around Fitch Bay and its watershed were identified. Furthermore, key issues happening in this region including erosion, sedimentation, eutrophication, cyanobacteria, species transitions and climate change were established. The following section attempts to link historical events and potential causes of these issues.

4.1. Erosion

Erosion is the result of numerous surface processes occurring on rock or sediment surfaces. Primary drivers for this system are wind and water, though bacteria, roots and seasonal transitions can also play a role. This phenomenon is more severe over deforested areas or regions with abrupt slopes, such as the northwest part of the watershed (MCI, 2006). The type of underlying rock ensures that some areas are subject to more severe erosion than others. Despite these factors, one of the leading causes of erosion is, and will always be, climate. (Ontario Ministry of Agriculture, Food and Rural Affairs, 2012)

Erosion processes have been explained for countless years in geographical and physical studies. Farmers knew of its action and had certain methods to maintain soil cover and prevent further problems. Changes in agricultural practices during the Green Revolution exposed soils to the elements for longer periods (Figure 4.1). At that time, small fields surrounded by trees were joined together to make tillage and other practices quicker through the use of machinery. Without trees to block wind and runoff, the soil was subject to nutrient depletion and loss of fertility. Removing vegetation cover destabilized the soil and it could explain the increase in hydric erosion seen over the last two decades (MCI, 2006).

Figure 4.1: ***Aerial view of a portion of the agricultural land present in 1945, by the Fitch Bay Narrows.*** *(Source:* Géomathèque *of the U*niversité de Sherbrooke, *A9426-65, 1945, scale 1: 20000)*

The problem was initially identified in Fitch Bay around the turn of the new millennium. The first erosion study, conducted in 2003 by Michaud *et al*. considered the impacts of hydric erosion using the Wischmeier and Smith method (1987). They estimated the average soil loss in Fitch Bay to be nearly 2.02 tons/Ha/year, with losses in arable soil approaching 6 tons/Ha/year (Bernard, 1996). Thus, what happened before that time making this study necessary.

Fitch Bay is located in a small valley surrounded by slopes on the north and west sides. There are three main types of soil in this region:

1. The Berkshire formation: schist originating from the upper Cretaceous period (144 million years ago), often present on mountain tops and easily fragmented in nature. Its flaky layered structure makes these rocks especially prone to erosion. (Cann, Lajoie, & Stobbe, n.d.). The minerals

are generally composed of mica, quartz and plagioclase, which have low fertility. In this formation, the schist is littered with pyrite. As these minerals leach out of the rock, they leave behind weak points in the encasing rock, making it more prone to breaking and erosion.

2. The Greensboro formation: a layer of silt and loam deposited before the Berkshire formation. The rocks date back to the mid-Ordovician period (460 million years ago). They were located inside the magmatic chamber of the Ammonoosuc volcanoes. Minerals are fine with a granitic mineral composition, making them very fertile but also easily eroded. They are what remain of the volcanic chain present during the closing of the pre-Atlantic Ocean. (Renshaw, 2008)
3. The Ascot formation: layer comprised of ultramafic-mafic plutonic rocks, felsic volcanic rocks and volcanogenic sedimentary rocks. This essentially means they are fine-grained dark rocks created at the surface of the Ammonoosuc volcanoes before Pangea. Formed in the early Ordovician period (490 million years ago), they have very low fertility. These hard rocks make erosion more difficult than the other present formations in this area but they are more easily eroded than the Canadian Shield. (Geological Survey of Canada, 1995)

When these soils are covered with trees or dense vegetation, they can resist erosion; but when the landscape is transformed, problems surface rapidly. Forest is the natural state of this ecosystem and any variation will increase erosion. When settlers first arrived in the 1850s, the land was transformed for agriculture, no matter the soil fertility. In the 1860s, the American Civil War led to the development of forestry in the region, which continued until 2006. Over the first years, there were large transformations in the area, leading to the beginning of erosion processes. Within 100 years, many farms and logging industries closed, allowing the forest to regenerate (Figure 4.2). The erosion of surrounding lands into the streams and surrounding waters most likely decreased as farms further from the streams were overgrown.

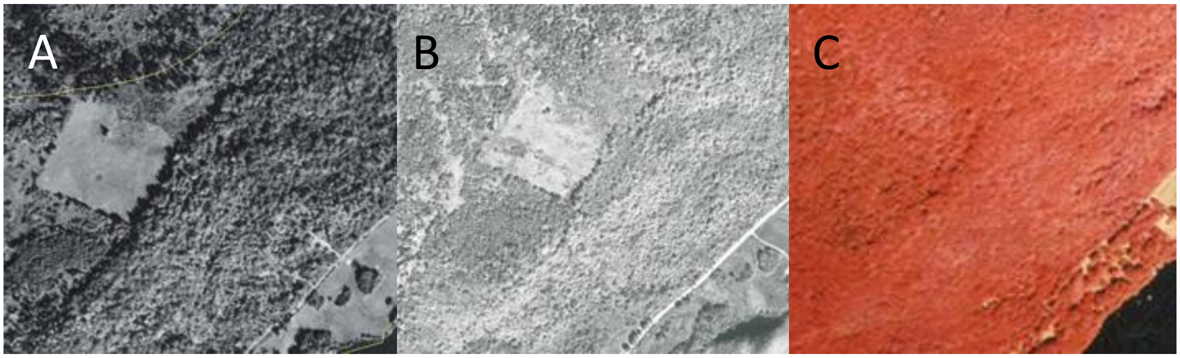


Figure 4.2: *Aerial images showing forest regeneration as agricultural land* *((a)1945) is abandoned ((b)1960) and turned back into a forest ((c)1989). (Source*: Géomathèque *of the* Université de Sherbrooke, *A9426-65, 1945, scale 1: 20000; R1323-100, 1960, scale 1: 15840; Q89105-141, 1989, scale 1: 15000)*

Unfortunately, most erosion occurs on slopes near and around the water's edge. When people sold their farms, many moved to the residential areas surrounding the Bay (Figure 4.3). Since the 1980s, this area has been developing rapidly, cutting trees and grasses in the floodplain and increasing risks of erosion. Shorelines were built up to slow erosion when in fact they increase it. Boats and other activities can also increase wave action leading to the same undesired effect.

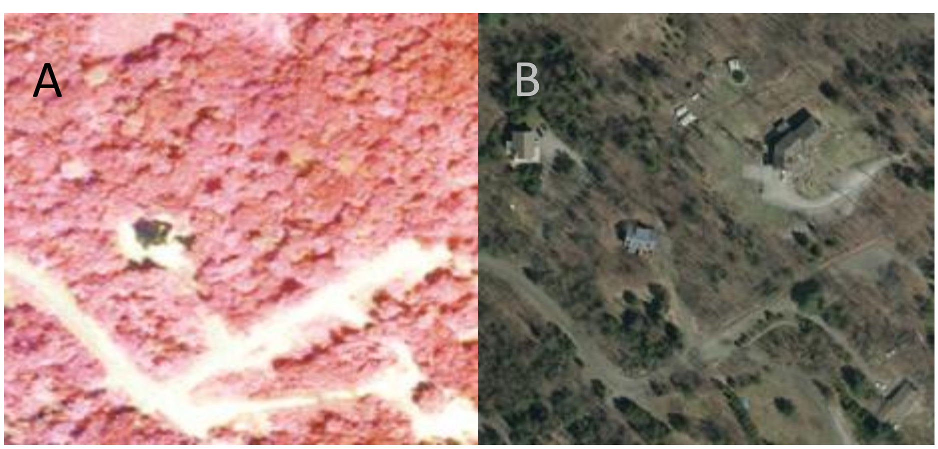


Figure 4.3: Aerial views from 1989 (a) and 2013 (b) showing the rapid expansion of residential areas. (Source: *Géomathèque* of the *Université de Sherbrooke,* Q89105-142, 1989, scale 1: 15000; Orthophotographies mosaic 1331h01, 2013)

4.2. Sedimentation

While erosion is the removal of soil particles through natural processes, sedimentation is their deposition caused by reduced water flow. Sedimentation is a known result of large residue particles carried at reduced turbulence. Erosion has the ability to put materials from land use into suspension. This includes chemicals from agriculture, wood from forestry (Figure 4.4), rocks and minerals from mining, and construction materials abandoned following the urban sprawl.

Figure 4.4: ***Forest cutting between the Bunker and Gale watercourses.*** *(Source:* Géomathèque *of the* Université de Sherbrooke*, orthophotographies mosaic 1313h01, 2007 & 2013) Common activity over the past two decades. Both could have carried many sediments into Fitch Bay. (MCI, 2006)*

Sedimentation was first noticed when dams were built. Downstream, waters have more speed and a better ability to erode surfaces, whereas upstream, waters are slowed allowing for precipitation of heavier materials. Therefore, dams built on the Magog River slow waters as they drain from Fitch Bay into Lake Memphremagog. Major flooding events are also known contributors as they carry more materials than normal. Once they get to the Bay, everything slows down. The rectification of the Fitch watercourse has increased sedimentation rates into the Bay as waters carry more materials. This case is visible by the formation of a delta at the inlet in Fitch Bay (Figure 4.5).

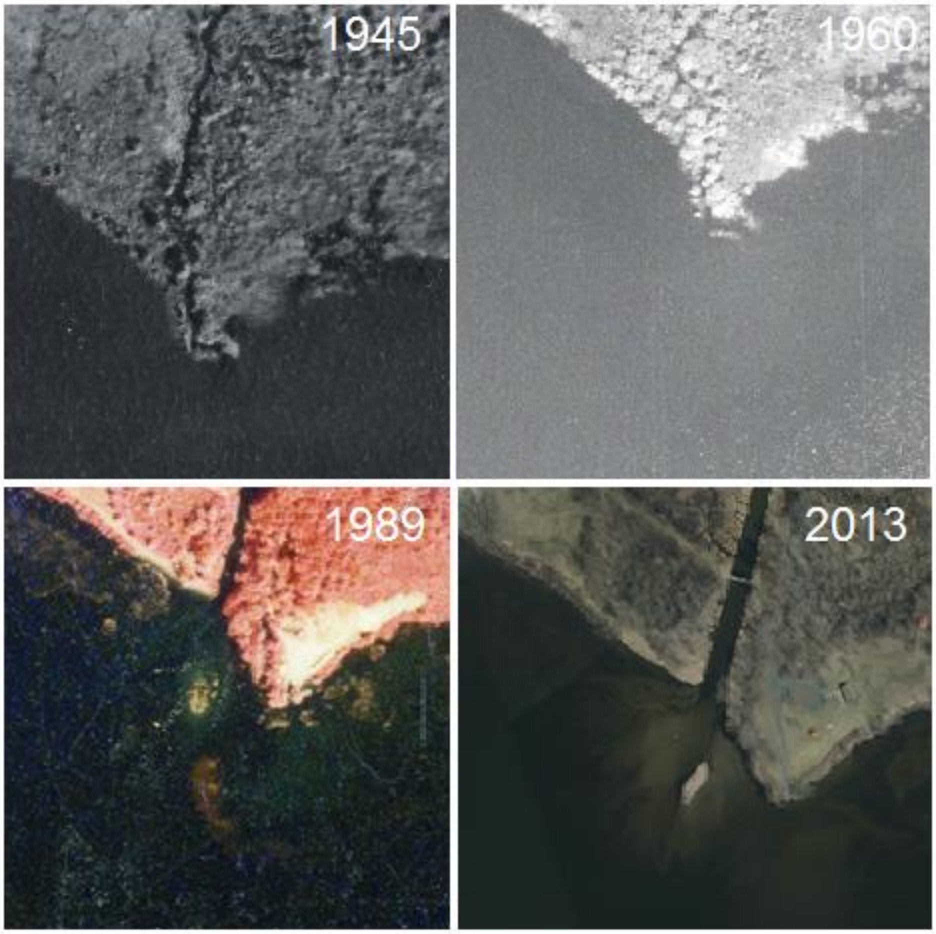


Figure 4.5: *Aerial images of the rectification in the Fitch watercourse and formation of the delta.* *(Source:* Géomathèque *of the* Université de Sherbrooke, *A9426-67, 1945, scale 1: 20000; R1323-100, 1960, scale 1: 15840; Q89105-141, 1989, scale 1: 15000; orthophotographies mosaic 1331H01, 2013)*

The carrying capacity of water is another concept worth exploring since more turbulent waters can haul a larger volume of pollutants and sediments. As the transparency of water decreases, the water in the Bay becomes more saturated with solid materials. Therefore, its ability to transport these particles is reduced. There is therefore more sediment that precipitates. The tendency shown through our results is for a decreased transparency as population and residential areas increase. The increase in human constructions came with the artificialization of the shoreline, reducing vegetation cover and destabilizing soils, which are more easily eroded without natural structures (MCI, 2006). Thus, it is why efforts are being made in local communities to naturalize these parts.

4.3. Eutrophication

Eutrophication is defined as the proliferation of algae due to increased nutrient content in the water column. In severe circumstances, it can lead to anoxia and kill aquatic populations present in the region. Currently in Fitch Bay, there is documented eutrophication, but no impact has been observed in accessible documents of dissolved oxygen levels. The main cause for this problem across North America is the nutrient input from fertilizers and chemical pesticides. (Poulain, 2017) This does not seem to be the case in Fitch Bay.

The Green Revolution expanded farms and implemented new machineries to enhance agriculture. Fitch Bay's hills and rocks made these innovations impractical. Thus, many farmers relocated to more fertile regions. A large portion of land dedicated to agriculture was abandoned before 1960's, which was when chemical fertilizers became more aggressive. Despite this reduction in agricultural practices, the highest levels of phosphorus were recorded in 1997 (MDDELCC, 2008). That same year corresponds to the lowest agriculture land use.

Flooding events occurred every time a new dam was built. Seasons with heavy rain or melt also brought additional water to the Bay. These were most frequent in the 1920s and 1990s. In the 1980s, regulations were passed to prevent new homes or cottages sending their sewage into the Bay. The number of non-compliant dwellings has been slowly reducing. Besides, the water treatment plant has been increasingly more severe about the quantity of phosphorus these installations can return to the water. Despite this, even fecal coliforms, high in phosphorus and nitrogen, continue to rise (MCI, 2015). Birds and fishes also excrete fecal coliforms, which indicates that their population variability may be at play.

Other potential sources of nutrient input include slowly decomposing organic matter. This is the result of the presence of bacteria in the bottom of the water column. In the spring, these organisms release nutrients as the soil return to a dirt-like substance. Since materials take time to decompose, events that took place decades ago could still be the cause and annual mixing in the spring, fall, (Pick, 2017) and caused by boats also put sediments back into suspension (Raymond & Galvez-Cloutier, 2015). When the first dam was built across the Magog River in 1888, people say that the marsh that used to occupy the land was submerged under two metres of water. This former wetland, high in nutrients from peat and decomposing grasses, is now undergoing a long process of decomposition. Residues from forestry that took place at the time, including bark, twigs, and sometimes lumber, have also littered the Bay's floor.

4.4. Cyanobacteria/blue algae

This issue was first reported in Fitch Bay in 1967 (MDDELCC, 2008). An alarming level of proliferation occurred in September, and it was the inspiration for several studies on the water quality of Lake Memphremagog throughout the 1970s. The population did not notice problems with blue algae again until 2005 (MCI, 2015). By 2006, cyanobacteria had attracted the attention of the community, and news of the problem in other lakes arose across the province. A total of 107 water bodies were affected by cyanobacteria. Actions were then taken to quantify toxic blooms in this area (MCI, 2015).

Cyanobacteria winter in the sediments and can make their way to the surface only once a year, during spring mixing. The earlier spring arrives, the more cyanobacteria make it to the surface. They have always been present in the Bay as they represent a vital food source for numerous fish species. They attract more notice when they group together to reproduce and use the sun energy to transform the nutrients in energy. Also, some cyanobacteria species can secrete some toxins during the blooming phase, causing irritation. No longer edible to fish populations, these blooms feed off high surface temperatures and light availability. (Poulain 2017)

Water flow is a natural deterrent as cyanobacteria cannot swim when they form algal blooms; but alone, they are a prey (Fortin, 2017). Eutrophication, due to its high algae production, provides shelter by slowing water. Multiple events could have contributed, such as the algae bloom observed in 1967. A dam was built upstream from Fitch Bay in 1960, reducing flow into the Bay. It was constructed to help with irrigation. Presumably, the water that does make its way through the river system is filled with nutrients. This is also the time when agriculture was intensifying its use of pesticides and subsequently, fertilisers. Together, these account for additional aquatic weeds and increased stagnant water, creating ideal circumstances for proliferation. For a while, they went unnoticed until a correction was built in Fitch Stream in 2006, increasing sediment carrying capacity through water movement.

4.5. Fish species

Regarding fish populations, the main influential factor is habitat. Fitch Bay is a nursery for countless species because of its shallow warm waters (Pouillot, 2017). It offers natural protection from predators that may want to destroy their offspring. Changes in environment have implications on the suitability of this habitat. The region was not always a Bay. Before the dams were built, it was known as a marsh or wetland. It is ideal for small fish that need protection for their eggs as it has minimal impacts on acidity. Besides, the narrow and shallow pathways are warm and protected from predators. Since the first dam in 1888, the region has been accessible to a larger variety of fish.

Humans also have an influence on species abundance. Fishing activities prioritize certain fish over others, namely carp and trout, while bass populations have skyrocketed. Caught bass is returned to the lake because fishermen prefer the flavour of trout or carp. The introduction of invasive species is another limiting factor for fish as they are usually better competitors for resources, or in the case of plants, will reduce the availability of food sources.

For some small fish, cyanobacteria are an essential part of their diet. When forming toxic blooms, this food source is eliminated and fish must find food elsewhere. Eutrophication can reduce dissolved oxygen content in deeper waters. This is not a problem in Fitch Bay yet; but could become one if conditions deteriorate. Finally, chemical inputs from boats and other sources outside of the water may impact alkalinity and dissolved oxygen in the water by saturating the water's carrying capacity and putting more materials into suspension.

5. FUTURE CONSIDERATIONS

A series of events have led to the development of environmental problems, most of which are identified above. In order to remedy these challenges, we must look to the future for long-term solutions. These originate from the results missing from this study and the action plan created that recommended this project.

5.1. For this study

The production of a historical portrait of the Fitch Bay watershed was one of the MCI's action plan objectives. The results of this study show that the action plan is adequate in what concerns solutions to the issues found in the region. Most results demonstrate that problems were not originally caused by the issues that intensify them today. What was obtained is the results of events that have taken place on the economic scale supported by scientific data from the past few decades.

The methodology of this document is often used in medical reports (Ali and al., 2017). Identifying some anthropogenic causes to current health issues is essential to obtain a better assessment of a disease's evolution. In this document, we have adapted this model to environmental issues; but it would gain in accuracy if coupled with a sediment core study. It would confirm some of the assumptions made here and allow a window into the undocumented past of environmental evolution. It may also give more precise dates as to when major changes took place and reveal some impacts that anthropogenic activities have had on water quality.

5.2. MCI's Action Plan

Over the winter of 2014-2015, MCI initiated the "Health of Fitch Bay: From diagnosis to solutions" project. The document presented a large range of recommendations that would help in correcting the identified issues. This project aimed to create a timeline that establishes some of the underlying causes of these problems. The action plan recommends the analysis and register of the different habitats and associated biodiversity around the Bay. It focuses on two main objectives: improving the water quality and preserving biodiversity and ecosystem functions.

The improvement of the water quality implies a decrease in nutrients, suspended materials, and pathogens. It also requires a reduction in mineral content. Phosphorus and chlorophyll A, along with water clarity, are good indicators, as they are precursors to problems with eutrophication and cyanobacteria.

Another objective of the MCI's action plan is to complete the characterization of agricultural areas and look for funding to improve practices. A great number of current issues can be linked to agricultural and residential practices.

Minimizing their impacts is among the most pressing challenges at present for the future in Fitch Bay, along with the study of climate change impacts.

5.3. The Influence of Climate Change

The greatest uncertainty when considering the future is predicting how climate change will affect the area. Not much is known but certain elements can be uncovered through careful analysis. Among other things, average temperature will rise. This implies that an earlier spring forms a longer window for cyanobacteria to reach the top of the water column. Higher temperatures also indicate that they have more energy and a stronger tendency to form blooms. When water temperature increases, its ability to carry oxygen is reduced thereby affecting living organisms, including fish. Warm weather could also reduce the fracturing of rocks in the freezing and thawing processes seen in winter, thereby reducing the erosion of rocks. More time without snow cover could increase the erosion of soils.

As global air circulation patterns evolve, more rain occurring are predicted over Eastern North America. Increased water volume leads to more movement throughout the summer and fall, which could decrease algal blooms as waters are not stagnant. This can also increase shoreline erosion and sedimentation into the Bay. There are no other locations along the Memphremagog watershed where it is feasible to place additional hydroelectric dams, which indicates that water levels will not rise further because of them. We are also too far from the ocean to be directly affected by sea level rise.

Other changes indirectly linked to climate change include acidification of water bodies. Ever since the industrial revolution, Canadian and American companies alike have emitted gasses into the atmosphere containing sulphuric and nitric acid. These are also produced by mining operations in the area and runoff waters from their tailings ponds. The region is built on shale containing only fragments of limestone; its neutralization abilities for acid. Eutrophication has been speeding up this process in lakes and rivers across the country though it has not occurred here yet.

Global overpopulation is another problem the world is facing. In Fitch Bay, it could lead to agricultural intensification, leading to the use of more chemical fertilizers as industrial processes deplete soil nutrients. Deforestation is also likely to occur to produce additional housing for this increasingly displaced population that migrates to all countries worldwide. The overall urbanization would cause a loss of natural land and increase atmospheric pollution.

CONCLUSION

This study provides insight into the environmental past of Fitch Bay and its surrounding watershed. Through the assembling of historical documents and previous studies, we have identified the contributing factors that led to the current state of the waters. This report contains most of the available information on the region assembled in a way that has rarely been done before. To complete the information gaps in water properties, additional research is required.

The methods used are versatile in that they could also be applied to the entire Memphremagog watershed, as well as elsewhere in the country. The only true changes would be the time allocated for digitizing aerial photographs and creating land use maps. Some additional changes would need to be considered outside the province, such as the reference legal system and sources of problems.

Similar studies have taken place in numerous other countries including the United States. This is among the first of its kind in Canada blending many elements beyond water quality and changes in aquatic systems. It has identified some underlying causes of environmental problems in the region that are not regulated to this point and may indicate future paths to restore water quality.

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