environmental news

University of Alberta
Environmental Research and Studies Centre

Volume 4, Issue 1
February 2004

Life in the Deep Freeze

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Flying above Ellesmere Island in a Twin Otter plane, you cannot help but be overcome by a sense of awe at the vast whiteness below you. Or at least I couldn't. And this sense of awe had only a little bit to do with the view.

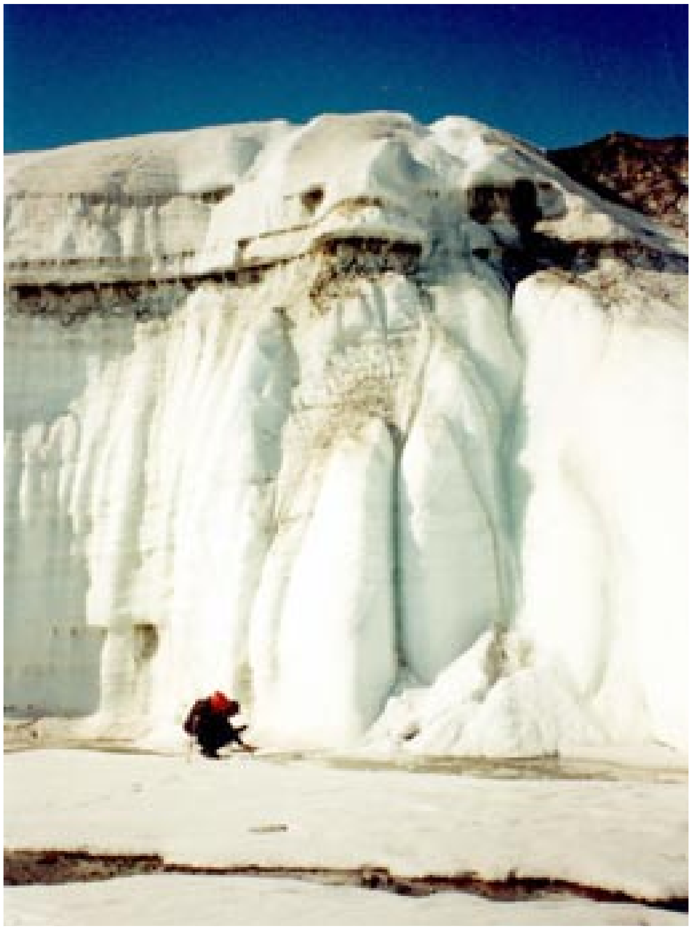
Ellesmere Island is about as far north as you can get (as a grad student) in Canada. Aside from the personal hygiene issues (too cold for ear wax or showers), staying there for two months in a tent was a bit daunting. And that sense of awe I mentioned? It never left me. It is hard to describe, but the best analogies I can draw are to standing in the middle of the desert or swimming in the middle of the ocean. But most of the time, I felt as though I were on another planet, almost certain in the knowledge that there was little life around me.

Since I was supposed to find something that could live in this harsh environment, this was not exactly the best attitude. So I started small—with bacteria. Bacterial life is one of the earliest forms in evolutionary history and can conquer every environment on Earth, including the vast, ice field on which I briefly lived.

Despite the spectre of global warming, the Earth is a cold planet. More than 70% of the Earth's fresh water exists as ice and by volume 90% of the Earth's salt water is below 5°C. Of the Earth's landmass, 14% is considered polar and approximately 20% of the soil ecosystem exists as permafrost. In these areas, where temperatures can reach as low as –60°C, microorganisms have unbelievably found a niche. In the frigid deserts of Antarctica, microbial communities eke out an existence within porous rock, away from wind and UV irradiation exposure. Pockets of sea brine in sea ice become oases for algae and bacteria. Tiny veins of liquid water between glacier ice crystals are perfect alcoves for these extraordinary microbes to inhabit. Many of these microbes have been carried from the far corners of the Earth by wind and precipitation and have adapted to live in these cold climates. Others are thought to be ancient life forms that have endured several global glaciations over the past 600 million years.

It is now proposed that wherever liquid water is found, no matter what the conditions, bacteria can survive. This idea has enthralled scientists and the public alike as it has made the prospect of life elsewhere in the solar system a distinct possibility. Recent speculations about a subsurface ocean on Jupiter's moon Europa and about melting beneath the Martian polar ice caps have intensified the search for microbes living in extremely cold environments, as these communities provide the closest Earthly analogues to ice-covered extraterrestrial environments.

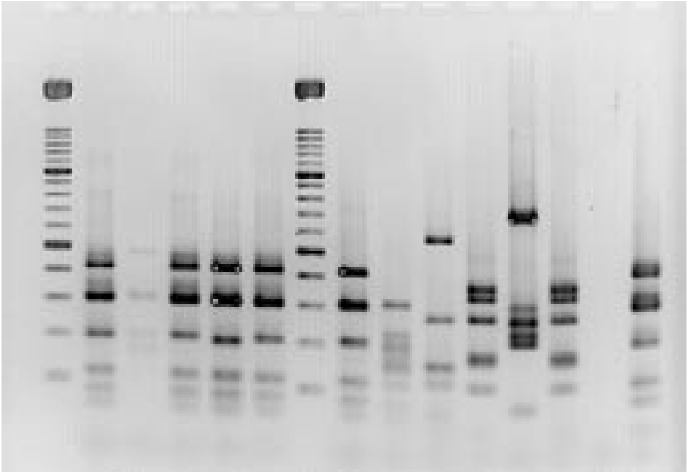
Recently, high numbers of microorganisms have been detected in the liquid- and sediment-rich ice layers beneath John Evans Glacier, a large valley glacier located on Eastern Ellesmere Island, Nunuvut, Canada. This glacier, like many others, has liquid water at its base where the ice mass and the land meet. Amazingly, we have found that microbes in this environment are active at temperatures as low as 0.3°C, and perhaps even colder. Our study attempts to characterize and compare the microbial communities beneath the glacier, on the glacier's surface (snow and ice), and in the soils and sediments adjacent to the glacier. Because of differences in physical factors such as ambient temperature, light and water availability, and temperature fluctuations, microbial community structure and composition may vary significantly between these three environments, even though relatively small distances separate them. Our results will help determine what kinds of microbes are present, where they might have originated, and what influence they are having on the local water chemistry. In the Arctic, nutrient cycling is extremely slow due to the cold temperatures, but microbial interactions act to catalyze these natural abiotic processes. By examining the hydrochemistry of the environments we can gain insight into the types of metabolic strategies that these organisms employ to survive in these environments, and also the precise biogeochemical impact of these communities on glacial environments.



Sampling at John Evans Glacier, Nunuvut

In previous studies, psychrophiles ("cold-loving") microorganisms have been examined using classic microbiological approaches, which involve isolating and growing microbes in a laboratory. These growth-based techniques are biased, however, in that they facilitate the preferential growth of certain microbes that respond well to the laboratory conditions over others that do not.

Because of the bias encountered with classical approaches, we are using modern molecular biological techniques that do not rely on growth of the microbes to characterize them. We isolate microbial DNA from the glacier samples, amplify it by polymerase chain reaction (PCR), and then analyze the DNA to determine what organisms were present in the original sample. In this way, the DNA serves as a molecular "fingerprint" which allows us to obtain a more complete picture of the microbial life beneath, on, and adjacent to the glacier. Through DNA analysis, we have created fingerprints for entire microbial communities within the three sample environments to allow comparison between communities. We have also created fingerprints for individual microorganisms to identify the major players within each community (see image below).



Our study indicates that the environments on, beneath, and adjacent to John Evans Glacier appear to be fairly distinct from each other, thus illustrating that the glacier bed may contain uniquely adapted organisms not present in the other terrestrial systems. Indeed, these communities may represent the type of life present elsewhere in our solar system and even the universe.

When I left the field, I doubted I had found anything beyond mere ice. But as we worked in the lab we were continually surprised by the diversity of organisms that we turned up and by the ability of life to thrive in even the most unlikely of places.

Bird-brained Inspiration and Experimental Design

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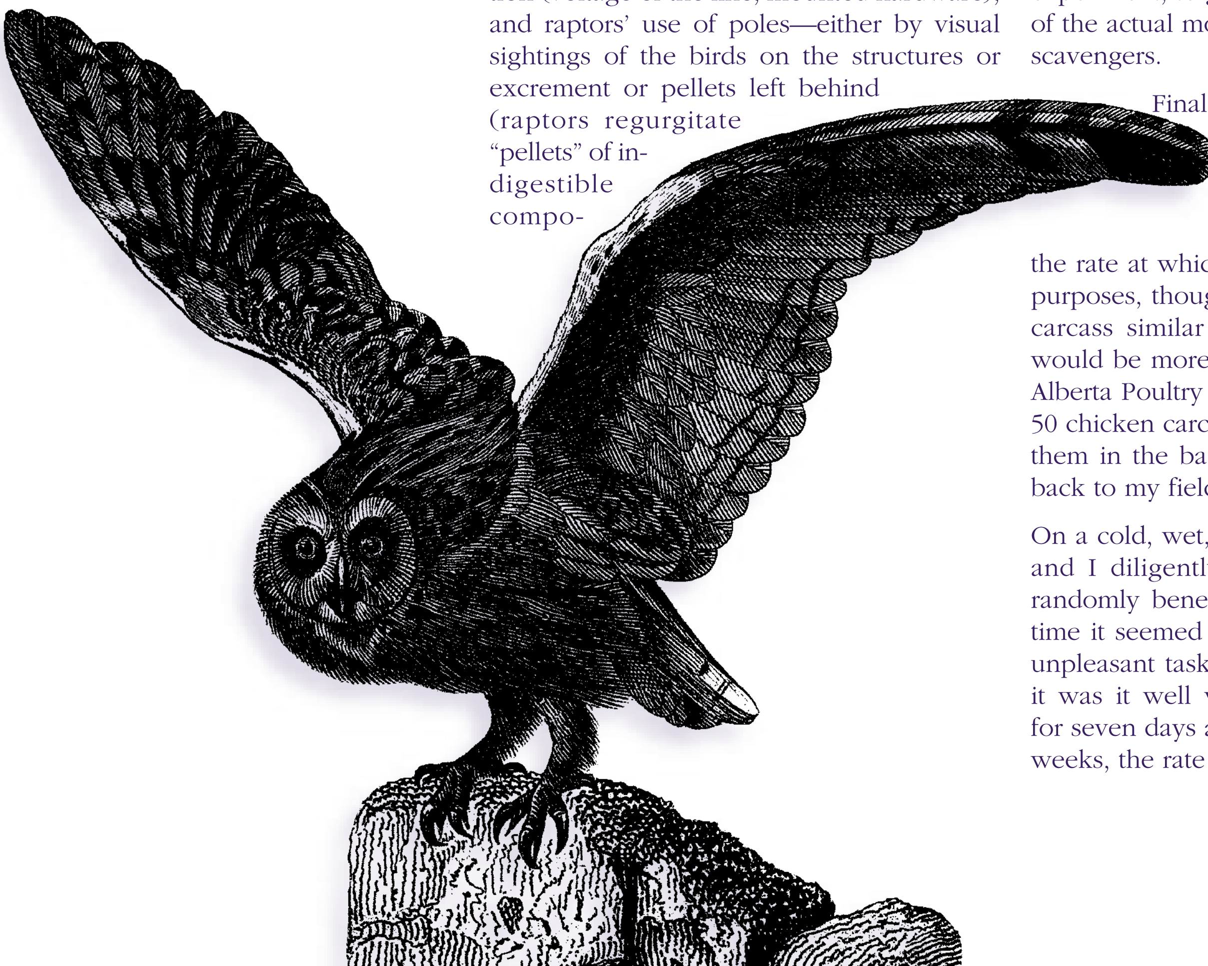
I never had much of an appreciation for chickens until recently. I mean, they are tasty, and one could even say cute, if looked upon in the right lighting. Beyond that however, I never gave them much thought—until this past summer.

I am a graduate student in the department of Renewable Resources. The focus of my Master's thesis is to study the mortality of raptors (hawks, eagles, owls, falcons and vultures) on power lines in Alberta. The project was outlined in the November 2002 issue of Environmental News ("Raptors vs. Lethal Lines"). Briefly, I am trying to discern which configurations of power poles pose the largest threat to raptor species in my study area (east-central Alberta). From there I want to determine which structural modifications are most effective in making these poles raptor-safe. Although electrocutions occur anywhere power lines and raptors co-exist, I have partnered up with one company, ATCO Electric, for this research.

I spent the summer of 2003 patrolling power lines looking for electrocution evidence such as avian carcasses (or parts thereof) and the presence of burn marks on the poles. I was also collecting information on pole configuration (voltage of the line, mounted hardware), and raptors' use of poles—either by visual sightings of the birds on the structures or excrement or pellets left behind (raptors regurgitate "pellets" of indigestible components of their meals such as bones and fur). Finally, I was collecting data on the relative abundance of raptor species in the area by surveying the landscape for three minute "point counts".

Whenever a carcass was found, it was frozen and later dissected to confirm the species, age and sex of the bird. Any physical damage sustained was noted as well. Most of the bodies that were dissected were the result of the servicemen from ATCO Electric turning in bird carcasses found during power outage investigations. My assistant and I did not find as many carcasses during our patrols as I had expected. I pondered the reason for this as I stumbled to avoid coyote and badger dens that dotted the landscape surrounding the poles—perhaps scavengers were toting away the very evidence I was looking for before we got there.

But how to account for this? Suddenly I remembered that during my literature review last year, I had scanned a brief description of a scavenging rate assessment that was part of electrocution research similar to mine. I dismissed the idea at the time, thinking that it did not pertain to my research. But now, I reasoned, I needed to do a similar type of experiment, to get a more accurate estimate of the actual mortality rate by correcting for scavengers.



Finally I get to the chickens. The above-mentioned literature described distributing rabbit carcasses beneath power lines and measuring the rate at which they disappeared. For my purposes, though, I thought using an avian carcass similar in weight to large raptors would be more effective. The University of Alberta Poultry Unit fulfilled my request for 50 chicken carcasses, and before long I had them in the back of my truck as I headed back to my field site.

On a cold, wet, miserable day, my assistant and I diligently distributed the carcasses randomly beneath 50 power poles. At the time it seemed insane to be doing such an unpleasant task in such harsh weather, but it was it well worth it. We assessed daily for seven days and thereafter weekly for six weeks, the rate at which the carcasses were disappearing. To our astonishment, over half of the carcasses were gone within the first seven days and continued to disappear steadily after that.

Although these data have yet to be statistically analyzed, the story emerging is likely very telling. Once the electrocution data collected during our patrols are corrected for scavenging using the data collected during the scavenging experiment, a much more accurate estimate of raptor mortality from electrocution will be possible.

As far as the electrocution evidence that was collected is concerned, some interesting trends appear to be emerging in the preliminary analysis. For example, despite there being roughly the same proportion of Red-tailed Hawks (Buteo jamaicensis) and Swainson's Hawks (Buteo swainsoni) in the area, not a single of the latter was collected. Perhaps the Swainson's Hawks have a natural aversion to the dangerous structures? Or maybe the slightly smaller size of the bird is enough to safeguard it from bridging the gap between two energized wires or an energized wire and a grounded wire?

Furthermore, it appears thus far that female raptors are more susceptible to electrocution than males. This might be explained by their larger size, or perhaps there exists a sex difference in the way in which they use the poles during hunting and feeding.

One thing I have learned is that the scavenging rate assessment, despite being an impulsive afterthought in my research design, has become an integral part of this study. Once those data are combined with the electrocution data collected during summer patrols, a much more accurate picture of the extent of raptor electrocution in my study area should emerge.

It is funny how one's research can evolve as it unfolds. The part of my research that took the least amount of time, preparation and money is now such a fundamental component of this study. I recommend any graduate student reading to pay attention if a light bulb goes off after your field season is well underway. What unfolds just may be the missing link in your project.

Impacts of a Petroleum Pipeline Failure on an Aquatic Environment in the Alberta Foothills

By Cam Stevens
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Alberta's landscapes of mountain, prairie and boreal ecosystems provide habitat for diverse assemblages of plants and animals, and ecological services that improve human quality of life. Alberta is also endowed with large areas of petroleum-bearing rock providing wealth for industry and Albertans. The energy boom began in 1947 when drilling struck oil near Leduc. Today, petroleum exports exceed $18 billion each year. Key to this growth and success has been improvements in pipeline technology and the 500,000 km of pipeline that links Canadian centres for supply and demand. This network includes massive steel conduits more than a meter in diameter that transports large quantities of petroleum across provinces and international boundaries. The majority of pipelines, however, are small flowlines and gathering lines that traverse short distances between wells and oil batteries where water and impurities are removed. In Alberta, these lines extend over 250,000 km.

A warning for a pipeline that failed in the summer of 2002 spilling freshwater, corrosion inhibiters, and industrial bactericides into beaver ponds in the Pembina Oilfield

The Energy and Utilities Board of Alberta reports approximately 700 pipeline failures every year which vary from small leaks to large ruptures, resulting in loss of the substance being transported. These failures typically occur in flowlines and gathering lines and are primarily due to internal corrosion from water and multiphase oil. Multiphase oil pipelines can carry unprocessed petroleum, minerals, salt water and gas with hydrogen sulfide. Water pipelines carry fresh or salt water removed from the oil (produced water) or either surface or groundwater that is injected in wells to displace oil to the surface. In 2002, the total reported spill volumes of hydrocarbon and produced water by companies operating in the province were 5,189 m^3 and 19,165 m^3, respectively. To prevent product loss from the predominantly steel pipelines, chemicals that reduce corrosion and accumulated debris are widely used. These chemicals can be released during leaks and ruptures in poorly maintained or old pipelines. While it is known that hydrocarbons and salts can harm the environment, to my knowledge,

Field enclosures used to assess the role of pond conditions in the growth and survival of larval wood frogs near Lodgepole, AB.

there are no experimental studies or field reports on the effects of pipeline maintenance chemicals, clear liquids that may appear harmless in a freshwater spill.

On July 10, 2002, I notified Penn West Petroleum that a pipeline leak may have been responsible for a large number of dead amphibians observed in a beaver-obstructed stream I was studying in the boreal foothills eco-region near the town of Lodgepole. The company immediately pressure tested nearby pipelines to discover that a freshwater line containing industrial bactericide and corrosion inhibitors had failed. Unfortunately, the company did not know when the break occurred or the length of time chemicals had leaked into the local stream before the spill was contained on July 12, 2002. The spill was classified as an intermediate leak of between 2 m^3 and 20 m^3. None of the spill was recovered. This unfortunate event occurred upstream of a field experiment and provided me with a unique opportunity to document the environmental effects of a typical pipeline failure in Alberta. As part of my PhD research project, I was using field enclosures to assess the role of pond conditions in the growth and survival of larval wood frogs on four beaver ponds. Coincidentally, one was the spill pond. The other three sites were similar reference ponds not affected by the pipeline failure. Each pond had six enclosures that were constructed of wood frames with nylon window screen on all sides and placed in the shallow margins of ponds (see photograph above). At the start of the experiment, 20 recently hatched larvae were added to each enclosure. On day 33 (July 10, 2002), I found that none had survived in the spill pond while in the three reference ponds, the mean survival rate in enclosures was 91 %. I also recorded 300 dead larval wood frogs outside the enclosures in the spill pond between June 19 and July 10. No dead larvae were observed in the reference ponds.

My field experiment clearly suggests that corrosion inhibitors and industrial bactericides in pipelines pose a threat to amphibians and pond ecosystems. Given this evidence, the high rate of failures from an increasingly extensive pipeline network represents a potentially large environmental impact in Alberta. I recommend i) the Energy and Utilities Board of Alberta compile field information on the effects of pipeline failures on the natural environment; ii) collaborative research between industry and university on the ecotoxicology of pipeline maintenance chemicals; and iii) the oil and gas sector implement new pipeline technology that reduces corrosion, such as internally-coated steel. Otherwise, the health of local ecosystems that provide us with so much may be severely compromised. The potential legal aftermath of pipeline failures should also be of concern for Penn West Petroleum and other companies in Alberta. A recent oil spill that wrecked an iguana study in the Galapagos Islands resulted in a court battle won by Martin Wikelski from Princeton University and the Galapagos National Park against an oil tanker's owner and insurer for US$10,000,000 in damages.

Bottom of the Ninth Inning for Elbow River Bull Trout

Ryan Popowich,
MSc Student,
Department of
Biological Sciences

OHV tracks in the Elbow River in close proximity to bull trout redds Photo credit: Greg Eisler (Trout Unlimited)

Snorkel survey on the Elbow River Photo credit: Jeff Smith

The Elbow River is one of many eastern slope rivers that bridge the gap between the snowy peaks of the Rockies and the prairies' flat plains. In addition to its natural intangible values, the Elbow River is cherished by recreational users; supplies water for livestock and crops; and, perhaps most importantly, provides drinking water for nearly one in six Albertans. The river is also home to a dwindling population of bull trout. A provincial ban on harvesting bull trout, implemented in 1995, has had mixed results; while some populations are showing signs of improvement, the Elbow River population is among those in decline. Having spent a great deal of time working to understand the habitat and foraging requirements of Elbow River bull trout, I now equate the relationship between human activity and these fish to that of a baseball pitcher and a batter.

The Elbow River begins its journey high in the mountains at Elbow Lake, approximately 80 km west of Calgary. From there, it charges through warm sub-alpine valleys, deep cold canyons, and out through treed flats on its way to the Bow River enroute to Hudson Bay. This path remained unimpeded for millennia until one day in 1930, when the river met the concrete of Calgary's Glenmore Dam. Bull trout, as well as other fish species, could no longer move freely between the Bow and the Elbow, potentially blocking historically important spawning runs. Strike one.

As with many water bodies in Alberta, the Elbow River is home to several introduced fish species. Exotic species threaten native biota in numerous ways including increased competition for limited resources, alterations of species composition, and hybridization leading to gene mixing. In doing so, alien species jeopardize conservation efforts by extirpating native populations and suppressing population recovery. In Alberta's rivers, brown, rainbow, and brook trout have been introduced for their fighting ability, appearance, or to provide a familiar angling experience for European settlers. The Elbow River is no exception—this invasive trio is competing with the dwindling bull trout population for limited resources.

Bull trout carry the biological burden of narrow habitat requirements, late sexual maturity, long life cycles and relatively long periods between reproduction events. In contrast, brook trout have broad habitat tolerances, short life cycles and an early spawning age, making them excellent competitors and invaders. In concert with suppressed bull trout populations and increased habitat challenges, an environment conducive to successful brook trout invasion and colonization is created. Because bull and brook trout are both members of the "charr" group of salmonids, the potential genetic disaster of hybridization between these species looms overhead. This trend is supported by my growing collection of suspected Elbow River bull trout X brook trout hybrids.

In addition, illegally farmed Arctic charr escaped from a trout farm into a tributary of the Elbow River between 1999 and 2001. Subsequently, efforts have been made to prevent the escaped Arctic charr from establishing a self-sustaining population; to date, the search continues and I am currently snorkeling the river in search of escapees. Should Arctic charr be discovered, there will be a total of four species of exotic trout in the river, all of which pose direct competitive challenges, and two of which constitute potential genetic time bombs. Strike two.

Another aspect of my research involves monitoring the movements of 30 adult bull trout implanted with radio transmitters in fall 2003. To my surprise and disappointment I have found five of the transmitters lying on the banks of the river. It would have been naïve not to anticipate that some poaching was occurring on the river, but five of thirty fish poached in a single month exceeded even my most cynical predictions. Assuming comparable poaching levels exist for untagged adult bull trout, poaching rates for one month approach 17%; this would explain the 25% reduction in bull trout redds (spawning sites) from 2002. Strike three.

There are other seemingly less significant threats present. A petroleum access road washed out depositing a large amount of sediment into a tributary and ultimately, the river. Additionally, an off highway vehicle (OHV) area resides nearby. Some of these outdoor enthusiasts drive outside of the OHV area, leaving quad tracks on the river banks and spawning gravel, and even on top of bull trout redds. Call it a coincidence, but two of the poached bull trout were located near a pool where illegal

OHV activity has been documented. Throw in poaching due to misidentification of bull trout by anglers, along with fecal contamination and riparian damage caused by cattle activity and we could probably call this a collective strike four.

My frustrations are compounded by the fact that obvious solutions exist, but have been met with resistance. The most obvious solution is to block the illegal OHV access to the river; unfortunately, efforts to date have been unsuccessful. Provincial budget cuts have also translated into decreased enforcement patrols in the area, reducing the chances of reprimanding poachers and users of illegal OHV trails. I am also not the first to suggest that cattle probably shouldn't be defecating in the drinking water of nearly one in six Albertans.

Finally, accidental poaching resulting from angler misidentification of fish could be reduced if anglers were required to pass a fish identification test in order to harvest fish in the eastern slope's streams and rivers.

When I first surveyed the river my reaction was "it doesn't get any better that this", but after spending a year in and around the river, I think that it could be a lot better. I'm not sure how many strikes this population can take, but I am sure that it is the bottom of the ninth. I'm hoping that when I begin tracking the Sheep and Highwood river populations this summer, the game isn't such a landslide.

The Current State of Boreal Lakes

By Michael Christensen
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If you were to hear the phrase "boreal lake", what would you imagine? Would you picture rich blue waters and lush green forests? Does the word "pristine" come to mind? In truth, to the human eye, a large number of our boreal lakes match this description and appear to be pristine. It is difficult to imagine that these systems are currently threatened by human activities. However, these areas are not as removed as we once thought them to be. Climate warming, acidification, stratospheric ozone depletion, exotic species, land-use changes, eutrophication, and overfishing are just some of the threats to the millions of lakes present in Canada's boreal zone. Our boreal lakes are an abundant source of drinking water, food, recreation, and natural beauty. These "ecosystem services" are performed by relatively few species in boreal lakes, and, as a consequence, even a small loss of biodiversity can severely jeopardize the integrity of these ecosystems. Unless awareness is raised and action taken, these once pristine systems will irrevocably change for the worst.

Partridge Lake, Killarney Provincial Park, Ontario

There are three factors that combine to create a general ignorance of the true state and future of Canada's boreal aquatic systems: Firstly, a 'stressed' lake looks just as pretty as a pristine lake in a brochure or in real life. A lake that has lost its entire native fish population due to introduced game fish, lost huge amounts of wetland vegetation due to shoreline development, and is concurrently being affected by climate change, acidification and increased ultraviolet radiation, appears just as healthy as a pristine lake. Secondly, media and environmental groups are generally silent about this issue. This fact, combined with the 'remoteness' of the boreal zone furthers the idea that these lakes are untouched. Thirdly, there is a misconception that science and industry have solved previous environmental problems (e.g. acid rain and ozone depletion), and will be able to solve current and future problems (e.g. global warming).

Despite decades of research and millions of dollars aimed at prevention, the ecological threat of acid rain has not been removed. While sulfur oxide emissions have been steadily decreasing since the 1970s due to industrial reductions, nitrogen oxides have not been controlled, and, as a result, have drastically increased.

Thus, the ecological threat of acid rain remains, and continues to affect organisms as large as fish, and as small as bacteria within lakes. In areas where acid deposition has been substantially reduced, lakes have taken decades to recover from the acidification, and in most cases, have yet to recover. In the few lakes that have naturally recovered from acidity, many of the organisms that were eliminated due to acidification have yet to return.

Super Stacks, Sudbury, location of some of the world's worst cases of acid rain

Even with the success of the Montreal Protocol of 1987 in reducing the amount of ozone-destroying particles released, the rate of stratospheric ozone destruction and coinciding increase of ultraviolet (UV) radiation has not slowed. The 'ozone hole' in the Antarctic has shown little evidence of shrinking, and recent data is showing that the ozone layer above the northern hemisphere is thinning at an alarming rate. Increased UV radiation will not only harm humans, but is likely to have devastating impacts on aquatic organisms. UV radiation is lethal to a wide range of organisms, particularly those that reside in the shallow areas of lakes where the sun's effects are the strongest. Many species of fish, particularly juveniles, reside in the shallows and will likely exhibit reduced numbers (if not entire elimination) if UV levels continue to increase.

Climate change is likely to be the single greatest threat to the stability, and perhaps even the existence, of many boreal lakes. Even if precipitation rates drastically increase, the evaporation rates predicted from an average warming of approximately 4°C will greatly reduce the net amount of water available in lakes and streams. Climate change will result in the water levels of many lakes dropping dramatically, and shallow lakes may be in danger of completely drying up. Warmer temperatures will threaten many aquatic species since many of these already live at their thermal optimums. As air temperatures rise, so will water temperatures, exposing many species to temperatures above their thresholds. For example, it was observed that lake charr (a species of fish) was virtually eliminated from an Ontario lake due to temperature stress during the warm El Niño summer of 1998. Climate change has the potential to disrupt a huge number of systems in Canada's boreal zone.

Acidification, ozone depletion and climate change have typically been thought of having very little in common. In reality, these stresses are closely linked, and the rise of one of them will result in greater impacts of all the stressors, creating a situation far worse then ever imagined.

The main connection between global warming, acidification and UV radiation in aquatic systems is a material called dissolved organic carbon (DOC). When an abundance of DOC is present in a lake, the water appears brown; when DOC is low, the water appears clear. DOC acts as a 'shield', filtering out UV radiation, light and heat. Lakes with a sufficient amount of DOC provide an environment that is cool, dark, and free from UV, which is highly desired by many aquatic species. Interestingly, global warming, acidification and UV radiation all act to drastically reduce DOC levels within a lake. Thus, the biota in a lake that is only being acidified (and not experiencing climate change or ozone depletion) must also cope with the additional stresses in increased temperature and UV radiation due to the loss of DOC. One quickly realizes that a lake that is concurrently experiencing all three stresses (as many lakes currently are) will experience substantial DOC loss and subsequent stresses.

Unfortunately, the situation of elevated temperatures, increased UV radiation, and acidification has never been tested experimentally, thus scientists do not know for certain the impacts of when these stresses interact. My thesis research will examine the effects of these three stressors upon boreal aquatic communities in an attempt to determine the magnitude of the threats posed on these systems.

Canada's boreal aquatic systems are currently threatened by a host of stresses, including a variety of others not discussed above. The reality of the situation is that each impact alone can be detrimental; in addition these stresses will interact with each other, creating worst-case scenarios. Although our freshwater resources are indeed massive, not a single area is free from our fingerprints, and these systems may be far more fragile than anticipated. Increased awareness to the true environmental situation of these systems is required if they are to be preserved.

University of Alberta

Environmental Research and Studies Centre

ISSN: 1705-2343

Environmental News is published by the Centre.
Editor Beverly Levis, Design: Creative Services
Articles, photos, commentary and suggestions should be submitted to:

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