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Silence is golden: boreal birds and industrial noise

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A motorcycle roars to life in the early morning outside your house. A car honks at a nearby intersection. A diesel bus passes as you walk down the street. These are all parts of the background noise of an urban environment. Have you ever spent some time out in the backwoods and remarked on just how quiet it sounds compared to daily life in the city?

Alberta's boreal forest to the north of Edmonton seems to be a vast tract of wilderness, and in many ways it still is. However, energy-sector development is heating up in our province's north. This surge in development has been the subject of much previous research at the University of Alberta, but it usually only looks at industry's physical effects – such as forest fragmentation, the creation of travel corridors for animals, and increased access for humans. I decided to study one of the side effects of industrial development – an increase in background noise level.

While many sources of anthropogenic noise exist in the boreal forest, the primary sources are compressor stations – facilities which regulate the flow of oil and gas through the pipeline system. There are over 3000 of them in Alberta, with at least a few present along every natural gas pipeline. These facilities emit noise in the range of 75 to 90 dB directly adjacent to the unit, which is comparable to the noise level generated by large trucks on a busy divided highway – except that the noise is constant, occurring 24 hours a day. This constant background noise could potentially affect many different types of wildlife.

My research examines a few ways in which chronic background noise may possibly affect boreal forest songbirds. Because birds communicate primarily through singing, it seems reasonable that they might be especially susceptible to negative effects of background noise. Most industrial noise is low-frequency – meaning it can travel great

Lucus Habib holds a freshly-banded male Ovenbird.

Weighing an Ovenbird in a cloth bag – they are small birds,with a typical mass of 18 to 20 grams.

Ovenbirds can be sexed by blowing away the feathers on the belly and checking the size of the cloacal protuberance.

distances through the forest and could interfere with bird songs.

One major way in which birds could be affected by industrial noise is through inhibition of mating. Female birds are attracted to males by the strength and quality of their mating song. Because of this, loud background noise could affect the signaller-receiver relationship. If a male's song is distorted, or doesn't travel as far through the forest, females may not be attracted to him. This could have severe consequences for him – if he can't mate with a female he won't be able to produce any offspring that year! The way I'm trying to assess this is by capturing and colour-banding male Ovenbirds. Once we have them banded, my team of observers and I are able to follow them and observe their behaviour to see if they are successful in attracting a mate. Then we can compare the information on males from quiet and noisy areas to see how they fare compared to each other. Previous work has shown that some birds have reduced mating success near roads, but it's difficult to say if that's because of the noise or other factors. By isolating the noise aspect, my research may be able to provide some insight.

A second way that chronic background noise could affect birds is by keeping them away from loud areas. When birds arrive from migration in the early spring, males choose territories that they think will help them attract females. It has been demonstrated that industry can affect birds' choice of territories, for example, certain species avoid areas near forest edges that border cutblocks or seismic lines. It's possible that noisy areas may have a similar effect – birds may avoid settling in them. If this is the case, we would expect to see lower numbers of birds in noisier areas. I'm testing this by performing counts of birds at a number of sites with varying levels of industrial background noise. I'll then look at the numbers all together, and in different species groupings, to determine if there are any patterns with increasing noise level.

The third thing I'm testing is if birds are able to adapt their songs to higher noise levels. Researchers in the Netherlands have found that birds in the city can raise the frequency of their songs enabling them to be heard above the urban noise. Can birds near industrial facilities in the boreal forest do the same? I hope to find out by using advanced microphones and computer software to record and analyse the songs of a few bird species.

Industry is capable of using various technologies to reduce noise emanating from compressor stations, but usually it is only done at facilities near human habitations. The possibility of broadening the deployment of these technologies exists, although it would be an additional cost for the energy industry. Hopefully, with cooperation from all sides, we can ensure that the boreal forest remains a place where you can hear the aspen trembling in the breeze.

Paleo-salmon variability

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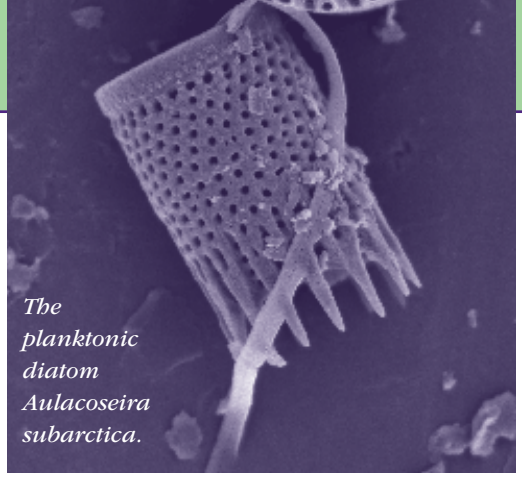
The Department of Fisheries and Oceans (DFO) recently announced the closure of the late-run sockeye salmon (Oncorhynchus nerka) fishery on the Fraser River, BC due to diminished returns of approximately one-third the preseason forecast. Miscalculations like this are not an anomaly – in 1992 half a million fish 'disappeared', followed by 1.3 million in 1994, while in 2002 three times the estimated number of spawners returned. In 2004, high water temperatures during the freshwater migration upstream were highlighted as the reason for 1.3 million 'missing' fish, presumed to have died or become disorientated during migration. Indeed there are a myriad of potential impacts to sockeye salmon during their life cycle which can affect populations. Commercial catch, climate variability, forestry, urbanization, agriculture or natural predation are examples of impacts which compound the already arduous journey to their natal spawning grounds (up to 1200 km). With all these obstacles and uncertainties it's hardly surprising that the variability of the sockeye returns continues to elude the modeling and monitoring of DFO.

While it is clear that variability exists within the life cycle of individual stocks (usually 4 years in the case of sockeye), what about the longer term variability on the scale of decades or even centuries? Is there a greater underly-



The planktonic diatom Aulacoseira subarctica.

ing trend in the abundance of sockeye being forced by oceanic or freshwater factors? Summarily, this is the question I am trying to answer through my research in the coastal and interior regions of BC. In order to attain a picture of the long term trend of salmon abundance there needs to be a natural data logger which has interacted with a certain stock for millennia. Lakes provide just such an interface because of the sockeye trait to use lakes as a rearing ground for their offspring. Spawning sockeye will lay their eggs in upstream tributaries of lakes and then die. The decomposition of the carcass either in the river or lake provides a large amount of nutrients (primarily phosphorous and nitrogen) to these freshwater ecosystems. High nutrient concentrations promote the growth of algae which enjoy those conditions and vice versa for low nutrient concentrations. This algae includes diatoms (Bacillariophyceae; single-celled organisms with biogenic silica cell walls). Because their ornate and resilient cell walls preserve well and are readily identifiable in lake sediments over thousands (or even millions) of years old, diatoms can be used as paleoenvironmental indicators of changing nutrient status as they are deposited on the lake bottom over time. In concert with the biological proxy, geochemical parameters are also used. For example, stable nitrogen isotope ratios have the potential to indicate past salmon abundance owing to the enriched composition of the salmon carcass in comparison to freshwater organisms and the subsequent enrichment of the freshwater ecosystem upon decomposition.

Recovered gravity (Glew-type) core from Clayoquot Lake. A clean sediment-water interface is evident.

In order to retrieve the lake sediment archive a coring device is required, which allows us to attain an undisturbed record of lake mud. The core is then sectioned on the lake shore into 0.5 cm intervals, representing 5 to 15 years depending on the amount of compaction and the amount of organisms within the lake for the specific sediment interval. The laboratory component of the research consists of identifying and counting the diatom microfossils to get an idea of the prevailing community and conducting geochemical analyses on the sediment organic matter for a given sediment layer. The sediment cores are then dated using short-lived radioisotopes (^{137}Cs and ^{210}Pb) and the results are compiled to chronicle recent environmental change in the lake and its surrounding catchment.

I spent a portion of this past summer on Vancouver Island, BC collecting sediment cores from a number of lakes on the west coast of the island. One of my main areas of focus was Clayoquot Sound, home of the infamous 1993 anti-logging protests to protect the old growth temperate rainforest. Clayoquot Sound was also home to the largest sockeye fishery on the island in the early 1900s until the mid to late 1970s when the population (once as high as 90,000 fish) collapsed. This stock has yet to recover despite the lack of commercial fishing.

One of my goals was to core Clayoquot Lake, which is the furthest upstream lake in the Clayoquot system below the Clayoquot Plateau. Access is by floatplane or foot and given the couple hundred pounds of gear we were dragging with us the choice of transport was relatively straightforward. Picking out the distinctive morphometry of the lake from the air wasn't too hard and we were set down on a gravel bar adjacent to the main inlet of the lake and spawning location for the returning sockeye. Standing on the shoreline of the lake with its steep walled densely vegetated sub-catchment, patches of clear cuts were clearly visible throughout the surrounding larger catchment. How will this affect the recent sediment record? Is there too much organic matter being contributed from outside the lake, leading to a dilution of the geochemical salmon signal in the mud? How much of the nutrients supplied by the salmon is retained and available for diatom growth and how much is flushed from the system? To answer these questions, I am currently trying to tease apart the bulk organic matter into that which is from algae (autochthonous) and that produced by decomposition of terrestrial biomass (allochthonous).

Clayoquot Sound is one example where human impacts appear to have irrevocably altered the natural variability of sockeye populations. If we want to continue to view salmon as a 'renewable resource', surely we need to understand this natural variability and protect the stocks when they're vulnerable to anthropogenic impacts. During 2002, DFO reported receiving numerous angry phone calls from fishermen about the constraints on their catch and calling the excess salmon allowed to migrate 'wasted fish'. This opinion seems to typify the lack of understanding of the positive feedback of the salmon's life cycle; from maturation in marine ecosystems to spawning and providing nutrients to both the freshwater and terrestrial ecosystems, which ensures a productive environment for offspring and increases their chance of survival. Through time the life cycle of the sockeye salmon is one which has demonstrated the interconnectedness of our planet's ecosystems.

What's on the dinner menu for polar bears in the Beaufort Sea?

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A polar bear cub of the year captured with its mother in the Southern Beaufort Sea. It is important to study the diet of all sex and age classes of bears, including mothers with nursing cubs, to see if any differences occur.

As I fly over the vast expanse of sea ice in the Beaufort Sea north of Tuktoyaktuk, NWT, in the Canadian Western Arctic, it is difficult for me to believe that anything can survive under such harsh and inhospitable conditions. Cruising at 140 km/h, at first glance all that can be seen from the helicopter when I look towards each surrounding horizon is snow covered ice. Before long, however, small dark spots appear on the white backdrop. As we approach I realize these are ringed seals lounging in the sun next to their perfectly round breathing holes. When the helicopter passes them overhead, the seals slip through their holes and disappear beneath the thick layer of Arctic sea ice.

Ringed seals never venture far from their breathing holes because they require an escape route from hunting polar bears that frequent this area on their unrelenting pursuit for food. Ringed seals are the main source of sustenance for polar bears in the Beaufort Sea and over the past 200,000 years these bears have evolved into highly specialized and skilled seal predators. I am reminded of this after another half hour of flying when we spot what is left of a ringed seal that has been partially consumed and left lying in the blood-stained snow. There are large polar bear tracks leading away from the kill site and it is clear that we have arrived on the scene not long after the bear's dinner. The pilot brings the helicopter down and I jump out to take muscle and fat samples from the seal that will be used for stable carbon and nitrogen isotope analysis.

As part of my graduate work at the University of Alberta I will compare isotopic signatures in polar bear prey items to signatures in polar bear tissues to determine the diet composition of the bears. It is known that a large part of these bears' diets is made up of ringed seals but it is less clear to what extent they may use other food sources such as bearded seals, beluga whales, bowhead whale carcasses, or walrus. Stable isotope analysis will help us to recognize the importance of various food sources because stable carbon and nitrogen isotopic signatures in an animal's tissues are similar to signatures found in their diet. This method of studying an animal's diet composition is particularly beneficial to ecologists because it allows for the measurement of assimilated nutrients over various time periods – weeks, months, years, or even a lifetime. In contrast to scat or stomach analysis, which only reveals an individual's last meal, stable isotope analysis provides a broader view of diet. For example, if we collect a blood sample, we can see what the bear has eaten during the past couple of months by looking at the isotopic signature in the red blood cells. The time frame represented by a metabolically active body tissue, such as blood, will depend on its isotopic turnover rate. In the case of metabolically inactive tissues, like the dentin in the annular rings of teeth, the isotopic signature in the tissue will represent the nutrients acquired at the time of growth. A small premolar tooth should provide a lifetime of information on the bear's feeding ecology. With fine subsampling of the teeth, we might even be able to look at annual variation in diet.

After collecting the seal samples I get back in the helicopter and we begin to follow the polar bear tracks away from the kill site. We only fly for a couple of minutes before spotting a large adult male polar bear walking through the snow. Andrew Derocher, my supervisor from the University of Alberta, has already prepared the darting equipment in anticipation of finding the bear. As the helicopter approaches, the bear begins to run and the pilot skillfully slides the helicopter into position. A dart is fired out the back window and lands between the bear's shoulders – a perfect shot. A few minutes later, the drug begins to take effect and the bear stumbles to the ice. The immobilization appears successful so we land the helicopter and cautiously approach the

Taking a fat biopsy from the thick rump fat of a sedated polar bear. Fat and other tissue samples will be used for stable carbon and nitrogen isotope analysis to determine the polar bear's diet.

bear. Once it becomes clear that it is properly sedated we begin our work.

For every bear captured, we take: a blood sample; a fat biopsy from the thick rump fat; a small clump of hair; a thin slice from the claw using a potato peeler; and a premolar tooth with the help of some simple dental tools. All of these tissues will be used later for stable isotope analysis to help estimate the diet of the bear. Each bear receives ear tags with an identification number and a tattoo on the inside of their lip. This will help to identify the bear in the future if they are captured again or killed by hunters. My project is just part of a larger mark and recapture study being conducted by the Canadian Wildlife Service to obtain population estimates for the two populations of polar bears that occur in the Beaufort Sea. These population estimates are important in order to maintain sustainable harvest quotas, ensure the proper management of polar bears in the Western Arctic, and provide insights on the possible effects of climate change.

Spring days in the Arctic are long as the sun does not set until after midnight. Today the weather is cooperating so we stay out late flying over the sea ice in search of polar bears. By the end of the day we end up capturing 13 bears including a couple of family groups. Throughout the study we will collect samples from all age and sex classes of polar bears to determine if their diets differ. Understanding the specific diet needs of various ages and sexes of polar bears will be important information for future conservation efforts.

While flying back to Tuktoyaktuk I can't help but wonder what the future holds for this majestic place and the wildlife that inhabits it. I think about the possible effects of climate change caused by increased carbon dioxide and other greenhouse gas emissions. I also remember the American Government's proposal to start major drilling operations in the nearby Arctic National Wildlife Refuge, which contains important maternity denning habitat for polar bears in the Southern Beaufort Sea. It is difficult to know how these and other changes will affect the area. However, I am glad I am here now to experience this unique ecosystem and capture a brief glimpse into its structure and function.

Designing protected areas for Canada's boreal region

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Renewable Resources

Shawn Leroux sampling woodland caribou habitat in northern boreal region.

Canadians love their parks, and every year, millions of Canadians migrate to their favorite parks to spend their vacation. For many Canadians, spending time in Canada's protected areas rekindles a connection with nature and enables us to escape from the rapid pace of city life. Although Canada's parks attract many people, few of these parks are large enough to support viable communities of the aquatic and terrestrial wildlife species that are native to the area. Even fewer parks are large enough to encompass the range of ecological processes, such as fire and large mammal predator/prey dynamics that define the ecological integrity of an area. This inadequacy of most Canadian parks reflects the eras of ad hoc park design, when parks were selected because of scenic beauty or because of political and economical expediency. Recently, conservation planning methods have begun to incorporate ecological criteria in the selection of parks to improve upon shortcomings of historical methods of park design.

Early ecologically-based conservation planning methods were developed in fragmented landscapes such as the United States, South Africa, and Australia. These conventional methods use mathematical algorithms that search the landscape for candidate protected areas that meet pre-set conservation targets for wildlife and culturally valuable sites. These algorithm-based methods are efficient at finding potential park sites that satisfy the pre-stated wildlife and cultural conservation targets however, these algorithm-based methods rarely consider ecosystem dynamics. Consequently, conventional conservation planning methods often identify parks that are too small to maintain large ecological processes (e.g., fire, barren-ground caribou migration) and likely will not maintain conservation targets through time.

The boreal region covers most of northern Canada from the Yukon to Newfoundland and is one of the last intact areas left in the world. The boreal region is inherently dynamic, shaped by natural disturbances such as fire and insect outbreaks. The boreal region also is under intense pressure from human use. For example, the Mackenzie valley pipeline in

the Northwest Territories is a large oil and gas development project that threatens to have long-lasting effects on the local ecosystems. Despite the pressure from human uses, only 5.8% of the boreal region has permanent protection and another 3.6% has interim protection.

For my master's research I am examining methods for designing a network of protected areas in the Canadian boreal region through a case study in the Mackenzie valley region of the Northwest Territories. I am using spatially-explicit dynamic simulation models to evaluate conventional park design methods, compare conventional park design methods to community-based land use planning, and develop criteria for determining the size of parks needed to maintain large-scale ecological processes.

In collaboration with researchers at the University of Alberta, I have developed a spatially-explicit dynamic simulation model, "CONSERV", that simulates forest fire and forest succession in the study area. The model was built using forest fire history data and studies of forest succession for the study area. To evaluate the efficacy of conventional protected area design methods, I develop potential park networks using the conventional methods. Then, I input the park networks into CONSERV, where I simulate forest dynamics on the landscape. I can evaluate the efficacy of each park network because CONSERV enables me to track the ability of parks to maintain selected wildlife species (Woodland caribou and waterfowl) and plants within park boundaries through time. If, after 250 years of forest fire and succession, a park network no longer maintains enough areas suitable for wildlife or plant species, these potential protected areas are deemed to be ineffective.

Any conservation planning in northern Canada must consider the existing community-based planning, where local communities make land use decisions throughout the planning process. I also am examining whether parks designed using conventional methods overlap with heritage sites identified by the Gwich'in and Sahtu communities in the study area.

Parks must be of sufficient size to maintain viable populations of plants and animals and the ecological processes that support these populations. With CONSERV, I can estimate the size of park required to encompass large-scale ecological processes. I use fire as the focal large-scale processes that I am attempting to capture within a park because fire is the dominant ecological process responsible for vegetation community development in the boreal. By simulating fire and forest succession on the landscape, I am able to determine the likelihood that different sized parks will maintain the ecological variation found on the landscape. A park that is not large enough to be representative of the surrounding landscape (i.e., have examples of all vegetation types within its boundaries) or that is vulnerable to be completely burned

One of Canada's treasures; Tombstone Territorial Park, Yukon

at any time may not achieve conservation goals through time. I recognize that the lands surrounding parks may also contribute to conservation objectives, therefore, my research is linked to the Canadian Boreal Ecosystems Analysis for Conservation Networks (BEACONs) project, which is looking at conservation planning both inside and outside parks in the boreal region of Canada.

The case study I am undertaking is timely because it facilitates pro-active conservation planning in the Mackenzie Valley. With this study, I will develop ecologically-based conservation planning methods that are suitable for large, intact areas such as the boreal region, contribute to understanding the complementarities of ecologically and community-based land-use planning, and provide guidelines for the size of parks required to maintain large-scale ecological processes in the boreal region. Canada still has the unique opportunity to establish protected areas that are ecological valuable in the boreal region. The results of my study will provide building blocks for further research on ecologically-based protected areas.

Remnants of a northern resident.

Awash with estrogens: identification and removal of estrogenic substances in domestic wastewater streams

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Products we use daily, including household cleaners, personal care products and the pharmaceuticals we consume, end up in the form of liquid waste that goes down the drain. In most cities across Canada, we have developed sophisticated means to mitigate the impact that wastes are having on the environment by sending our waste through wastewater treatment plants or lagoons prior to discharge into our rivers, lakes or oceans. However, the question remains, are wastewater treatment plants continuing to be effective in protecting aquatic organisms from potential hazards?

Researchers in the fields of analytical chemistry, toxicology and environmental engineering have discovered that estrogenic substances in domestic wastewater effluents from major cities may cause adverse reproductive effects in exposed fish including full male-to-female sex reversal. Synthetic female birth control hormones, hormone replacement therapy drugs, natural female hormones along with other synthetic chemicals which are estrogen analogs such as plasticizers used to maintain flexibility in various polymers and surfactants used in soaps and detergents have all been implicated in the estrogenic effluents conundrum. The problem has already become so urgent that the city of Toronto has implemented a sewer use by-law regulating the levels of specific estrogen analog surfactant chemicals allowed in the sewer system.

Uncertainty remains as to which specific chemical culprits cause the majority of the estrogenicity in effluents and potential biological effects in exposed aquatic organisms. The first stage of my project under the supervision of Dr. Ian Buchanan (Civil and Environmental Engineering) and Dr. Michael G. Ikonomou (Fisheries and Oceans Canada) involved sampling select number of Waste Water Treatment Plants (WWTP) from different cities that use different treatment practices in Canada. This provided material to develop and refine analytical methods and to perform a survey of the types and amounts of various environmental estrogens found in these wastewaters.

In a wastewater sample, it is difficult to achieve extremely low detection limits for trace level pollutants such as estrogens due to the complexity of this matrix which often leads to interferences in traditional chemical detection methods. One objective of my study was to achieve the lowest detection level possible.

A chemical method based on Gas Chromatography – High Resolution Mass Spectrometry was developed allowing the detection of up to 30 environmental estrogens and related compounds simultaneously at part-per-trillion levels in a minimal sample volume of wastewater. Additionally, an *in vitro* yeast screen, modified to contain estrogen receptors was used to provide levels of non-specific net estrogenicity. This assay provides more toxicologically relevant information which would be complementary to that provided by aforementioned chemical method. The resultant data allow us to determine if the major environmental estrogen culprits have been found in our chemical analysis.

Most recently, the effectiveness of wastewater treatment plants to remove environmental estrogens has been highly scrutinized in the scientific literature and in some cases there have been reports of higher levels occurring in the plant's final effluent than what came in to the plant.

WWTPs are designed and operated to remove maximum amounts of biochemical oxygen demand, suspended solids, and nutrients such as nitrogen and phosphorous from the incoming wastewater so that the processed wastewater is less offensive to organisms in the receiving water body. Most of the reduction of harmful substances is achieved by using a biological reactor where ideal conditions for the growth of microgranisms are maintained. In the bioreactor, incoming wastewater or plant influent provides the "food" for the micro-organism

Some of the personal care products and pharmaceuticals found in many homes.

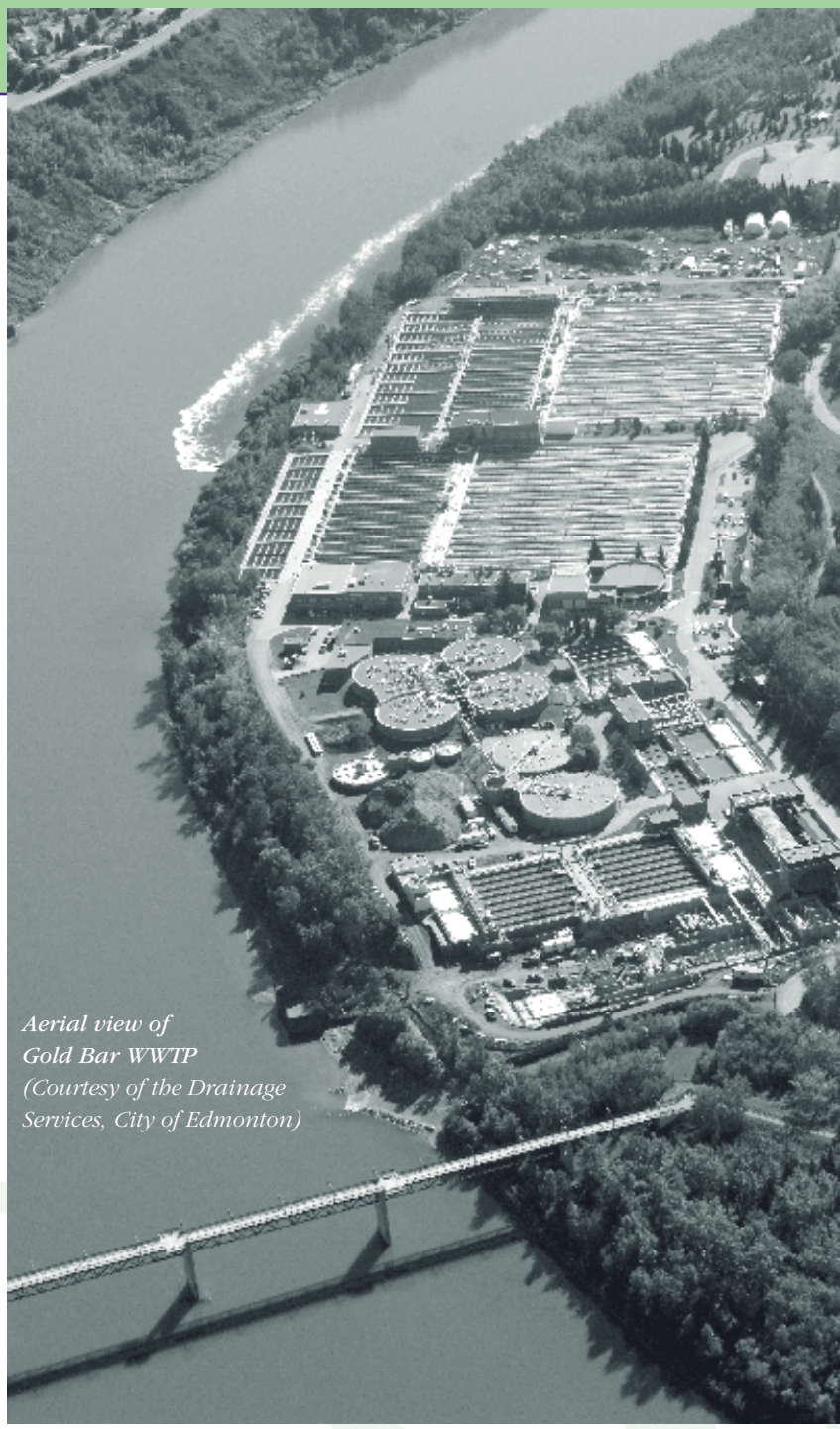
which in turn will break down complex and offensive organic components in the waste into more stabilized products or CO_2 and H_2O in the case of complete mineralization. Another important treatment method in which offensive components may be removed from the liquid waste stream involves physical adsorption to a solid growth of microorganisms or sludge.

The second phase of my research project will involve tracking the most notorious environmental estrogens identified in that wastewater throughout the treatment process at Edmonton's Gold Bar WWTP which serves a population of 720,000 and discharges 260 mega-litres per day into the North Saskatchewan River. It is anticipated that this study will shed light on current unknowns as to if and where environmental estrogens are being effectively removed in the wastewater treatment process.

In some cases, micropollutants such as environmental estrogens are resistant to conventional treatment methods. In situations like Edmonton and the North Saskatchewan River where wastewater is discharged into surface waters which may become drinking water, the human health implications of potential exposure to environmental estrogens and other wastewater pollutants becomes important.

Maureen Nakonechny (MSc student) under the supervision of Dr. Mohamed Gamal El-Din (Civil and Environmental Engineering) is working on a new treatment method based on advanced oxidation processes (AOPs). This treatment process generates and uses hydroxyl radicals to degrade contaminants in a manner similar to natural degradation processes, but on a much faster scale. Hydroxyl radicals may be generated through the decomposition of dissolved ozone or hydrogen peroxide in water via irradiation with UV light or added catalysts together with UV light, among other techniques. This research will focus on ozone-based AOPs, which will involve various treatment combinations of dissolved ozone, hydrogen peroxide and ultraviolet radiation.

The results of our work will provide a concrete measure of how effective treatment methods may be in dealing with environmental estrogens in wastewater and will also advance knowledge of treatment options. Ultimately our goal is to reduce the potential risks to the health of humans and the environment.



Aerial view of Gold Bar WWTP (Courtesy of the Drainage Services, City of Edmonton)

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