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TOXIC METALS WEIGH HEAVY ON BIRDS

Metals are natural components of the Earth's crust. In trace amounts many, such as zinc and iron, are even essential parts of our diets. Ever since the onset of the industrial era in the mid-1800s, however, the extraction of minerals for human uses has also greatly increased the availability of many toxic metals in the environment.

Mercury and lead—two metals of particular concern when it comes to the health of wildlife—have been the subject of ongoing study by scientists at Environment Canada since the early 1970s. Both metals are listed as toxic substances under the *Canadian Environmental Protection Act* for their potentially harmful effects: mercury for causing behavioural and reproductive problems, and lead for causing organ failure and death. Although they are found in both terrestrial and aquatic habitats, the manner in which they are ingested puts waterfowl, fish-eating birds and mammals, and predators and scavengers that feed on these species at the highest risk of being poisoned.

Mercury is released into the atmosphere by volcanic eruptions, forest fires and other natural processes, but at least 50 per cent of its total in the environment comes from human activities. Once it has entered the atmosphere, it can be carried thousands of kilometres and deposited far from its source. The steady anthropogenic (human-caused) increase in environmental mercury in recent years is largely a by-product of fossil-fuel combustion, waste incineration and other industrial operations, such as smelting.

Mercury is not easily taken up by organisms until it is transformed into methyl mercury through a bacterial process that occurs much more readily in aquatic than terrestrial habitats. This process is enhanced by certain environmental factors, including the acidity of the water into which the mercury falls. Sulphur and mercury follow similar deposition patterns, so lakes in eastern Canada—which receive the highest levels of acid rain—also experience the most serious mercury contamination problems. In a recent study, 16 per cent of Common Loon eggs collected in eastern Canada were found to have mercury concentrations above the threshold associated with reproductive impairment in birds, while none from western Canada did. Those with the highest concentrations were from lakes affected by environmental acidification.

Wildlife technician Nev Garrity moves an Atlantic Puffin so he can collect the egg in its nest burrow for analysis of mercury levels.
Photo: Dan Busby, Environment Canada

The presence of organic carbon also enhances methylation by boosting the bacterial activity needed for the process. Studies conducted by Environment Canada scientists near hydro-electric projects in Quebec show that Ospreys feeding on newly flooded land experience considerable elevations in methyl mercury levels due to the availability of organic carbon from decaying material. Some scientists are concerned that global warming could also increase methylation by creating conditions that further stimulate bacterial activity.

As a result of these and other environmental factors, lakes located near each other that receive the same mercury input do not necessarily exhibit the same level of contamination in their wildlife. For example, tests carried out at a lake near an abandoned mercury mine in British Columbia showed extremely high levels of mercury contamination in the environment, but lower-than-expected levels in the lake's fish and waterfowl.

Methylated mercury is ingested by invertebrates and fish, and biomagnified as it moves up the food chain. Although outright mortality is rare, mercury levels found in fish-eating birds such as loons, mergansers, Ospreys, eagles, herons and kingfishers are often more than sufficient to cause reproductive impairment and aberrant behaviour. Such increased levels have been linked with lower egg production, an increased number of infertile eggs, and a higher incidence of embryonic or early hatchling mortality. A 1996 study showed that loon chicks also spend less time on their parents'

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A Bald Eagle eating a goose. Predatory birds, such as eagles and hawks, can be poisoned by consuming dead or wounded waterfowl embedded with lead shot.

backs and more time preening on the surface of lakes as exposure to mercury increases—behaviour that saps their energy and increases their odds of being attacked by predators.

Environment Canada scientists have undertaken many studies on the sources, fate and effects of mercury in the Atlantic provinces, which receive three times as much of the toxic metal today as they did 150 years ago. Although local sources are partly to blame, the area is uniquely prone to receiving large quantities of air pollution through atmospheric deposition from sources in central Ontario and the New England states. The fact that many lakes in the region are highly acidic and that some have naturally high geological levels of mercury means that conditions in some lakes pose a serious risk to wildlife.

The severity of the contamination became evident when biologists discovered that the reproductive success of Common Loons in Kejimkujik National Park, Nova Scotia, was half that of loons in the rest of Canada. Blood tests determined that mercury levels in the birds' blood were, in fact, higher than in any other loon population in North America. And, until stronger mechanisms are put in place to curb mercury emissions from international sources, the situation is not likely to change.

Where things are changing is in areas of the country where domestic controls have resulted in declining local or regional emissions. Data collected through Environment Canada's long-term monitoring program show that mercury levels in Herring Gull eggs from sites across the Great Lakes are about half what they were in the late 1970s and early 1980s.

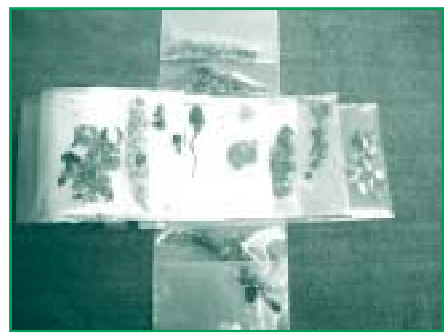
Unfortunately, in remote northern environments, which act as a sink for airborne pollutants due to global weather patterns and other factors, scientists are seeing the opposite trend. Increased mercury levels are being seen in northern birds, seals, and beluga whales, as well as in sediment profiles of northern lakes. The reason is that a sizable fraction of the mercury in our atmosphere is global in origin—coming from sources as far away as China and India, where emissions are less strictly controlled.

To test this theory, Environment Canada biologists have been monitoring mercury levels in the eggs of three Arctic seabirds that nest on Prince Leopold Island in Nunavut. Two of these—the Thick-billed Murre and Northern Fulmar—have exhibited dramatic increases in these levels between 1975 and 1998, while the third—the Black-legged Kittiwake—has remained constant.

Since the three species breed in the same area, scientists have determined that these differences are the result of differences in the contamination levels of biota consumed on their wintering grounds. Both murres and fulmars spend a greater proportion of the year at higher latitudes than kittiwakes do. Northern Fulmars undertake a transoceanic migration to the open seas of the northeast Atlantic in winter, and Thick-billed Murres winter in open waters off southwestern Greenland. Kittiwakes, on the other hand, winter along the eastern seaboard from Newfoundland to Florida, where mercury concentrations are now lower than they once were because of reduced point-source emissions.

A similar trend has been seen in seabirds on Canada's Atlantic coast. Since 1972, Environment Canada biologists in Newfoundland have monitored levels of mercury and other contaminants in the eggs of the Double-crested Cormorant, Leach's Storm-Petrel, Herring Gull and Atlantic Puffin. The four species feed in different parts of the ocean, so their contaminant levels reflect different sources of mercury pollution. Birds feeding further out to sea are more affected by long-range atmospheric transport, while those feeding closer to shore receive more contaminants from local sources, such as pulp mills and other industries.

The two species that feed on the open ocean—the storm-petrel and puffin—showed significant increases in mercury levels, while the other two species, which feed closer to shore, did not. Levels in storm-petrel eggs increased a whopping 73 per cent over the past three decades, and approach or exceed the range that causes reproductive problems in other birds. Since storm-petrels spend the entire year feeding on krill on the surface of the North Atlantic and Arctic oceans, scientists say



Lead sinkers and weights attached to lost fishing line are often found in the gizzards of dead loons, as shown in these bagged samples.

there could be a chemical process occurring at the marine surface that allows mercury to enter the food chain more directly. They are currently undertaking population counts and examining the birds' reproductive success to determine the impact this trend is having on the species.

While mercury levels in the environment are on the rise, lead is falling, thanks to the phasing out of leaded gasoline in many countries, and a national ban on the use of lead shot for hunting most migratory game birds. The lead shot ban, which came into effect in 1999, reduced the amount of lead being deposited in the Canadian

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environment by hunters each year by about 40 per cent.

This form of lead enters the food chain when lead shotgun pellets or lead fishing sinkers or jigs are mistakenly ingested by birds, or when dead or wounded animals that contain shot are eaten by predators or scavengers. Shot is ingested primarily by ducks, loons, grebes, cranes, herons, geese, swans and other birds that dig in the bottom of lakes and ponds for food and grit for their gizzard—the part of the stomach they use to grind up food. Sinkers and jigs, on the other hand, are eaten primarily by loons when they consume lost fishing bait with the line still attached.

Stomach acids break the lead down easily, and allow it to enter the bloodstream where it damages the vital organs. Lead has a relatively high intrinsic toxicity, so adverse effects have been seen at even low levels of exposure. Lead poisoning can kill a bird within days, or cause it to die slowly from weakness or starvation.

The precise number of waterfowl killed in Canada each year as a result of ingesting lead shotgun pellets has never been estimated. However, before the ban, lead shot was considered a potentially significant cause of mortality and sub-lethal poisoning in game ducks. Lead poisoning killed more than half the Trumpeter Swans released at Wye Marsh, Ontario, as part of a reintroduction program, and was a common occurrence among swans wintering in southwestern British Columbia. In 1992, a wingbone survey conducted by Environment Canada biologists revealed that over 20 per cent of young-of-the-year Mallards and Black Ducks in Prince Edward Island, New Brunswick and Ontario had elevated lead levels.

Birds of prey were also affected. Studies of Golden Eagles and Bald Eagles in Saskatchewan, Alberta, Manitoba and British Columbia in the mid-1990s revealed that about 12 per cent of those found dead had been lead poisoned, and a further 5 per cent had elevated lead concentrations. Scientists suspect that the eagles were poisoned by eating dead or wounded waterfowl and other game containing ingested or embedded shot. This theory is supported by an American study that examined the content of undigested waste regurgitated by raptors such as eagles and owls, and found that 75 per cent contained lead shot. Scientists say that, were it not for this natural behaviour, the number of raptors with lead poisoning could be considerably higher.

Although scientists report finding fewer lead-poisoned eagles in recent years, and preliminary results of recent waterfowl wingbone surveys indicate that lead levels are declining, the problem hasn't disappeared. Lead takes decades or even centuries to break down in the environment, so although shot may sink out of sight in soft-bottomed marshes, it could persist in habitats with hard, rocky sediment. Many lake bottoms contain up to 180 000 lead pellets per hectare, and some heavily hunted ones contain millions. And, despite the fact that it is illegal, some hunters still use lead shot for waterfowl instead of the somewhat more expensive non-toxic alternatives.

Canadian Wildlife Service researchers collect Herring Gull eggs from an island in the Bay of Fundy. Photo: Dan Busby, Environment Canada

Lead also continues to enter the environment at target ranges and through the hunting of big game, small game, and upland birds, such as pheasant, quail, and grouse—all of which activities are under provincial jurisdiction. Environment Canada is currently involved in studies of lead levels in upland game birds, raptors and songbirds, and has found that the frequency of elevated lead exposure in these species is often as high or higher than was observed for waterfowl before the ban on lead shot came into effect, indicating that the problem could be more widespread than originally imagined.

One of the most serious lead problems, however, remains the ingestion of small lead sinkers and jigs by loons in lakes where sport fishing is popular. Anglers lose about 500 tonnes of lead sinkers and jigs in Canadian waters each year. Even the smallest of these is sufficiently large that it is virtually certain to kill any loon that eats it. Lead poisoning accounts for 5–50 per cent of recorded adult loon mortality in Canada, and is the leading cause of recorded death among adult Common Loons in North America during the breeding season.

In 1997, Canada banned the use of lead fishing sinkers and jigs weighing less than 50 grams (the maximum size typically ingested by loons) in all national wildlife areas and national parks. Since sport fishing beyond these boundaries is under provincial jurisdiction, Environment Canada's efforts have focused on education and outreach programs. Since 2000, wildlife officers in Ontario—the province with the greatest angling pressures—have placed advertisements in sporting magazines and attended hunting and fishing shows to raise awareness of the impacts of lead on wildlife. This year, for the first time, they will also be holding special sinker and jig exchanges in Toronto and Ottawa, so people attending the shows can trade their lead fishing tackle for non-toxic alternatives.

Potential control measures for dealing with regional mercury use and emissions are also under provincial jurisdiction. However, Environment Canada's research has played a vital role in international negotiations on the issue—including the signing of an action plan to reduce mercury emissions and foster cooperative research and monitoring by the New England Governors and Eastern Canadian Premiers. The more information scientists are able to gather on the impacts of heavy metals on birds and other wildlife, the better equipped decision-makers at all levels of government will be to impose stricter controls on the entry of these toxic substances into our environment. S&E

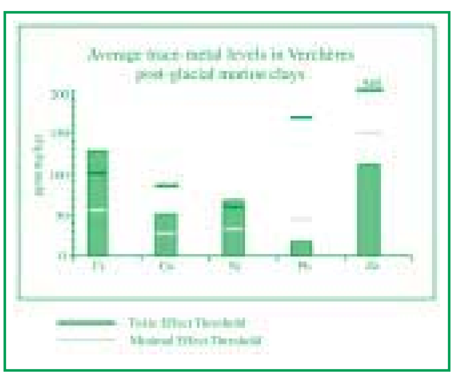
DIGGING UP TROUBLE ON THE SEAWAY

Scientists take sediment cores from the bottom of the St. Lawrence River to determine levels of trace metals in post-glacial marine clays exposed by decades of dredging.

The St. Lawrence Seaway has undergone extensive dredging over the past 160 years to ensure a navigable channel for the ever-increasing number of ships that ply this vital trade route. While a depth of three metres sufficed for sailboats and steamships in the 1800s, the bottom of the busiest section of the river has since been scraped to nearly four times that depth to make room for today's mammoth ocean-going tankers and container vessels.

Removing sediment from the floor of the Seaway has also dug up some serious problems. Once buried under a thick layer of sediment laid down during the pre-industrial era, post-glacial marine clays that were deposited on the floor of the Champlain Sea more than 12 000 years ago are now exposed along the entire length of the river from Montréal to Quebec City. Despite the fact that these clays are naturally occurring, they contain concentrations of heavy metals that are considered potentially toxic to bottom-dwelling fauna, such as worms and crayfish.

Before sediment-quality criteria were created for the St. Lawrence River in 1992, dredged material was usually dumped along the shoreline or used to enlarge existing islands. Since then, if a chemical in the sediment has been found to exceed the Toxic Effect Threshold defined by these criteria, the sediment has had to be disposed of at a properly confined landfill site that is suitable for contaminated material. This has significantly increased the costs of dredging, and could be a major impediment to future development on the Seaway, as dredging may prove to be the easiest solution to the problem of declining water levels.



Average trace-metal levels in post-glacial marine clays in the Verchères region of the St. Lawrence show that both chromium (Cr) and nickel (Ni) exceed the Toxic Effect Threshold.

To take a closer look at the situation, Environment Canada's St. Lawrence Centre, in cooperation with Fisheries and Oceans Canada, Transport Canada, Public Works and Government Services Canada, the Quebec Ministry of the Environment, and the *Société de la faune et des parcs du Québec* embarked on research to better document background levels of toxic chemicals in these sediments and evaluate their distribution and potential "bioavailability", or availability for uptake by organisms in the environment. Since the project began in 1999, some 200 samples and 50 sediment cores have been taken at more than 100 sites in the Verchères–Contrecoeur, Lac Saint-Louis, Lake St. Francis and Sorel–Trois-Rivières areas.

Samples were analyzed using three different acid extractions—a very aggressive solution that solubilizes all of the mineral "phases" or non-organic components of the sample, including those that are not degraded by normal processes; a less aggressive solution that solubilizes fewer phases, but still some that do not normally break down; and an even milder solution that solubilizes only the most reactive phases that are likely to release their metal content.

Results from the most aggressive extraction carried out on post-glacial marine clays showed that chromium concentrations averaged very near the Toxic Effect Threshold, and exceeded the threshold in 85-95 per cent of samples from the Verchères and Lake St. Francis areas. A smaller percentage of samples contained copper and nickel levels above this threshold, and average concentrations of the two metals significantly exceeded the Minimal Effect Threshold. No other metals in this post-glacial material had average concentrations that exceeded this lower threshold.

Concentrations of chromium, copper and nickel in post-glacial marine clays fell close to or below the Minimal Effect Threshold when analyzed using the least aggressive extraction method, which more closely reflects the concentration of contaminant that is potentially bioavailable. One reason for these lower levels is that post-glacial clays were created by unusual physical circumstances, as rocks were crushed into fine grains by the incredible weight of retreating glaciers. Therefore, although the total concentration of these chemicals is high, the deposited material itself may be less likely to break down and release its contents under normal circumstances.

Although several bioassays have been carried out that support the theory that the Seaway's sediment is not toxic to benthic fauna, further tests are required. Current sediment-quality criteria also require reconsideration, as technologies and knowledge have improved significantly since the criteria were established nearly a decade ago based on similar thresholds for the Great Lakes. Next summer, sediment sampling will continue further downstream in an effort to better characterize regional variations in contaminant concentrations. Once the study is completed, the St. Lawrence Action Plan's Committee on Dredging Operations will evaluate the results and determine next steps toward better protecting both environmental and economic interests on the Seaway. S&E

ENVIRONMENTAL IMPACTS OF ROAD SALTS

Every year, about five million tonnes of road salts are applied to Canada's highways, streets and sidewalks to help make them safer for winter driving and walking. Meltwater from roadways and snow dumps and releases from patrol yards where salts are stored have resulted in unnaturally high concentrations of chloride from these salts entering soil, groundwater and surface water.

To determine the exact impact road salts are having on the environment, a group of government and non-government experts conducted a comprehensive five-year science assessment on the issue. With the publication of the assessment report in December 2001, the federal Ministers of the Environment and Health concluded that road salts that contain inorganic chloride salts with or without ferrocyanide salts are harmful to the environment, and recommended that they be added to Schedule 1 of the *Canadian Environmental Protection Act, 1999*. Under the Act, the Government now has two years to develop control measures for these substances, and a further 18 months to finalize the measures.

Road salts do not pose a risk to humans; in fact, the most commonly used salt on our roads is the same one used on our foods. However, exposure to high levels of chloride—a principal constituent of road salts—can be harmful to plants and wildlife. The highest annual loadings of road salts are in Ontario and Quebec, with intermediate loadings in the Atlantic provinces and the lowest ones in the western provinces.

Road salts enter the environment when snow and ice melt, and are dispersed into the air by splashing and spray from vehicles, and as windborne powder. Chloride ions have an affinity for water, so they ultimately make their way into surface water—either in runoff, or through the soil and groundwater. Toxicity data indicate that about 10 per cent of aquatic species will be adversely affected by prolonged exposure to chloride concentrations greater than 240 milligrams per litre (mg/L), with changes in populations or community structures occurring at even lower concentrations. Algae are particularly sensitive, with shifts in lake populations associated with concentrations as low as 12 mg/L.

Chloride concentrations as high as 82 000 (mg/L) have been observed in meltwater from salt-storage yards, 18 000 mg/L in runoff from roadways, 8500 mg/L in streams, 4300 mg/L in small rivers, 4000 mg/L in ponds and wetlands, and 300 mg/L in rural lakes. Field measurements have shown that applications of road salts in certain rural areas can increase chloride concentrations in lakes a few hundred metres away from the road edge.

A front-end loader fills up a salt truck at a storage facility in Alberta. Photo: Terry Ream

A number of field studies have documented damage to vegetation and shifts in plant community structure in areas where road salts are in heavy use. Elevated concentrations of chloride and sodium in the soil and air damage the foliage and roots of sensitive plants, and reduce growth and flowering. Terrestrial plants may be affected by soil concentrations greater than 68 parts per million (ppm) sodium and 215 ppm chloride, while sensitive soil-dwelling micro-organisms can show effects at even lower levels. Areas with such soil concentrations extend up to 30 metres from the road edge and salt storage yards, while the impact of aerial dispersion can extend up to 200 metres from the edge of multi-lane highways where de-icing salts are used. Vegetation along watercourses that drain roadways and salt-handling facilities is also affected.

Damage to vegetation and shifts in plant community structure resulting from the use of road salts also affect wildlife that depends on these plants for food or shelter. Behavioural and toxicological impacts on mammals and birds have also been associated with exposure to road salts. Some birds that ingest salt may be poisoned outright, while behavioural changes in others increase their vulnerability to being hit by a moving vehicle. Evidence suggests that road salts may play a larger role than previously estimated in the road-deaths of federally protected migratory birds.

Environment Canada will invite federal, provincial, territorial and municipal transportation and environmental authorities, industries, environmental groups, and other stakeholders to participate in the development of control strategies for road salts starting early this year. Possible options could include reducing losses at salt storage sites, better engineering of snow dumps to control run-off, improved salt application technology and meteorological forecasting tools, and the use of more environmentally benign alternatives in sensitive areas. S&E

STUDY SHOWS WETLANDS RECOVER FROM SPILLS

Aerial photo of the experimental oil-spill site near Sainte-Croix, Quebec, during the first high tide.

Wetlands are among nature's richest habitats, providing food, water and cover for a diversity of animal life. In Canada, few lakes and rivers encompass as much freshwater marshland as the St. Lawrence River, with more than 26 000 hectares from end to end. This wetland is a critical stopover area for tens of thousands of ducks, geese and other birds that cross the River during spring and fall migration.

The environmental significance of the St. Lawrence River wetlands has raised concerns about the impact that a large oil spill could have on plant and animal life in this fragile habitat. The River is a major transportation route for oil tankers and other ships, and about 140 accidental hydrocarbon spills occur on it per year. So far, most have been sufficiently small or remote that responders were able to keep them from reaching these sensitive areas. Spills that do reach wetlands pose a major challenge to responders because traditional mechanical clean-up methods—such as pumping or dredging sediment or using high-pressure water jets—cause extensive damage to aquatic vegetation.

To learn more about the behaviour of oil in freshwater marshes, and to test and develop new remediation methods for use in these fragile habitats, Environment Canada and Fisheries and Oceans Canada staged an experimental petroleum spill in a marsh on the St. Lawrence River in June 1999. The Quebec Ministry of the Environment, the US Environmental Protection Agency, France's *Centre de documentation, de recherche et d'expérimentations sur les pollutions accidentelles des eaux*, and several Canadian and American universities were also involved in the scientific study. The Canadian Coast Guard and regional emergency response agencies used the field trial as a training exercise to deploy oil spill response countermeasures, such as containment booms.

A site was chosen in the Sainte-Croix region, near Quebec City, because it contains most of the plant species found in the St. Lawrence, is not home to any endangered or threatened species, and is far enough away from urban areas that potential impacts on human health from the project were deemed minor. More than a year was spent planning for the spill—developing an emergency contingency plan, and carrying out environmental assessments. Public forums were held both before and during the experiment, to ensure that the residents of Sainte-Croix were consulted with and informed about all aspects of the spill.

The goal of the project was to determine the behaviour and biological effects of oil spilled in a freshwater marsh, the natural recovery rate of the habitat through bioremediation—that is, the breakdown of hydrocarbons by native plants and bacteria—and the effect of certain treatments and procedures on this natural recovery process. Although bioremediation had proven effective at degrading oil in marine wetlands, this marked the first time in North America that it had been tested in a freshwater marsh.

To simulate a real spill, the oil used in the experiment was obtained from a refinery on the St. Lawrence, and artificially "weathered" by outside aeration so that part of it would evaporate, as would typically occur over the time that it would take a real spill to reach the shore. At low tide, approximately 800 litres of oil were sprayed directly onto the sediment and plants in 20 experimental plots, each measuring about four metres by five metres. The whole area was surrounded by a containment boom, and each plot was contained by a net with absorbent pads along its top edge to exclude birds and control the loss of oil during the rising tide. The site itself encompassed an area of about 750 square metres, or about .05 per cent of the total intertidal zone of the Sainte-Croix marsh.

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In an actual spill situation, the shoreline is frequently re-oiled by successive tides. To simulate the results of this occurrence, the plots were raked after the spraying to facilitate the penetration of the oil into the sediment. As a result, after the first tide there was no evidence of free-floating oil outside the area of the experimental plots. Elevated oil concentrations in the sediment within the plots were similar to that reported in actual spill events.

Immediately after the spill and through the following three summers, scientists made regular trips to the site—taking sediment samples to chart changes in the composition and concentration of the oil, conducting water quality tests, measuring plant biomass, and conducting bioassays to assess changes in toxicity. Cages containing native fish and snail species were monitored to determine the impact of the oil on aquatic wildlife.

While some plots were left as is, others were treated with agricultural fertilizer in the hope that the added phosphorus and nitrate would stimulate the growth of bacteria in the sediment, and thus increase the rate of oil degradation. The fertilizer was re-applied every couple of weeks during the first season, since sediment tests confirmed that the tide diluted and washed it out quite quickly. Some plots had their vegetation cut down regularly, to gauge the impact of plant growth on oil degradation.

Within the first 21 weeks of the experiment, natural physical processes (i.e., dilution by tides and currents) that effectively dispersed the oil into the environment removed approximately 10-15 per cent of the oil spilled in the marsh. Thirty-five per cent of alkanes and polycyclic aromatic hydrocarbons—both oil components of known environmental concern—were reported to be degraded by natural bacteria in the sediments. High-technology tests carried out with the assistance of the National Research Council showed that bacteria adapted naturally to degrade the oil—their populations increasing dramatically while there was oil present, and decreasing after it was gone.

Scientists noted a significant reduction in the toxicity of sediments in all the oiled plots within the first year. The predominant vegetative species (*Scirpus pungens*) recovered within a single growing season, proving that these freshwater plants (a major food source for Canada Geese) are highly resistant to the effects of oil contamination—likely due to the fact that their root systems extend beyond the depth of oil penetration.

In terms of habitat recovery, while the addition of agricultural fertilizers did not enhance the degradation rates of oil, it did stimulate plant growth significantly, and reduced toxicity at a faster rate than in untreated plots.

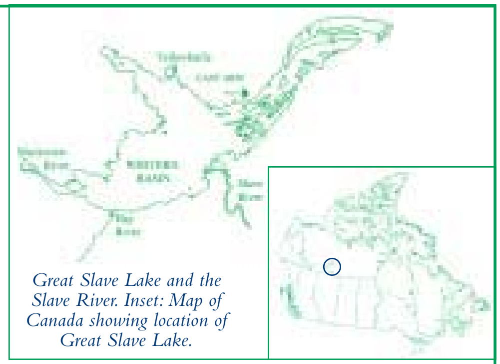
Enhanced plant growth in two adjacent oiled plots in mid-growth season as the result of fertilization.

Fertilized plants in both oiled and un-oiled plots were approximately half a metre taller than untreated plants by the middle of the first growing season. Even more surprising was the discovery that, although there was no fertilizer applied the second year, accelerated plant growth was observed in the treated plots the following two summers. The fact that these aquatic plants appear to store fertilizer as nitrogen in their roots means that minimal treatments have long-term effects on habitat recovery.

Plots with enhanced plant growth and those in which the vegetation was cut down exhibited no difference in oil degradation rates. However, there was enhanced oil degradation in the surface sediment of the plots, while oil at deeper sediment levels biodegraded at a slower rate. These tests provide strong evidence that oil degradation is linked to the availability of oxygen—a theory that scientists are currently testing by adding chemical oxidants to anaerobic sediment at an industrial site contaminated by hydrocarbons.

Although the results of the study have only recently been made public, they have attracted considerable international interest. Numerous scientific papers on the subject have been presented at national and international symposia in Canada, the United States and Europe. Furthermore, an upcoming issue of the *Bioremediation Journal* (CRC Press) will be devoted to the publication of research papers resulting from this project. The findings will be used to develop a suite of new techniques for determining when sites are considered sufficiently free of contamination, as well as new protocols for dealing with oil spills that threaten wetland habitats on the St. Lawrence River. S&E

PROTECTING A NORTHERN GREAT LAKE



Great Slave Lake and the Slave River. Inset: Map of Canada showing location of Great Slave Lake.

When Canadians think about the Great Lakes, Superior, Michigan, Huron, Erie, and Ontario are usually the first to come to mind. But evidence that there may be trouble brewing at another Great Lake further north is causing serious concerns for local populations and environmental scientists.

Great Slave Lake, located in the Northwest Territories, is the deepest lake in North America and the fourth-largest in Canada. The shores of the lake between Yellowknife and Hay River are home to more than half the Territory's population, and fish from its waters support subsistence, sport and commercial fishing.

Community members from Fort Resolution dissect a fish as part of a study investigating contaminant levels in Great Slave Lake.

In recent years, industrial development along the Peace and Athabasca rivers has raised concerns that persistent organic pollutants (POPs) could be transported via the Slave River into this previously pristine lake. Also of concern is the long-range atmospheric transport of pollutants to the region from other industrialized parts of the world. To get a clearer picture of the extent and sources of the problem and its effects on the food chain, researchers from Environment Canada's National Water Research Institute and Fisheries and Oceans Canada began a series of studies under the Northern Contaminants Program and the Northern River Basins Study.

The scientists collected samples of surface and core sediments from the Western Basin of the lake—the region most directly affected by the Slave River—and surface sediments from the East Arm. They also gathered biological samples, such as plankton, whitefish, lake trout, and burbot, from offshore areas near Fort Resolution (in the Western Basin) and Lutsel K'e (in the East Arm).

Analyses of the sediment samples showed the presence of POPs—including polychlorinated biphenyls (PCBs), toxaphene and DDT—that originated from human activities. Polynuclear aromatic hydrocarbons (PAHs) and dioxins and furans, which can have both natural and anthropogenic sources, were also discovered. Concentrations of PCBs, DDT, and PAHs were substantially higher in the Western Basin samples than in those from the East Arm, pointing to the Slave River as a significant source of contaminant loading to the lake floor. Long-term atmospheric transport became a more significant source of contamination in the East Arm as the distance from the river mouth increased.

When researchers analyzed the biological samples, they found an increase in POP concentrations from plankton to whitefish to predatory fish. This was expected, as POPs biomagnify with each step in the food chain. However, they were surprised to discover that, despite higher concentrations of contaminants in the surface sediments of the Western Basin, biological samples in the East Arm tended to contain higher tissue concentrations of these contaminants. This finding suggests that suspended sediments in the Western Basin may reduce or dilute the amount of contaminants that can be absorbed by invertebrates and fish. Research continues to gain greater insights into these processes.

The same joint research group worked with partners from the Fort Resolution community to determine whether the decommissioned Pine Point lead-zinc mine was causing heavy metal contamination of the sediments, water, and fish in Resolution Bay. The study established that this was not occurring; however, mercury concentrations in the muscles of some large pike and burbot were found to be close to the guidelines established by Health Canada for frequent fish consumption. In 1999, a new study was launched with community partners from Lutsel K'e and Fort Resolution to monitor long-term trends in contaminant concentrations in fish in Great Slave Lake. In 2000, Fort Smith on the Slave River was added as a monitoring site.

Researchers believe that contaminant concentrations in Great Slave Lake will decrease as atmospheric sources decline. Northern lakes such as this one are still relatively pristine, but, as scientists are now well aware, the continuing health of these lakes cannot be taken for granted and must be carefully studied and monitored. S&E

S&E Bulletin

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