S&E SCIENCE AND THE ENVIRONMENT BULLETIN S&E
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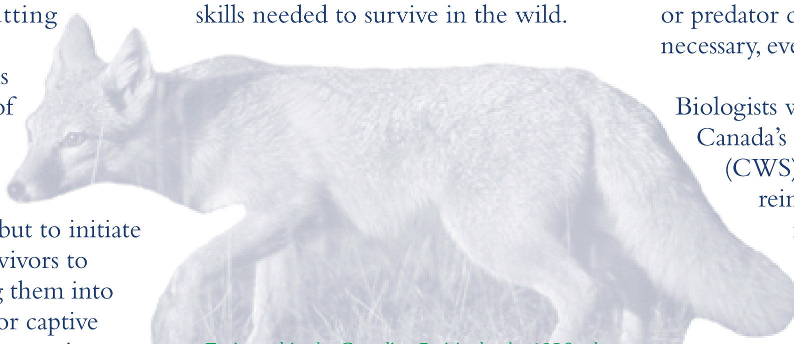
COMING HOME

The spectacular grace of a Peregrine Falcon as it plunges from a cliff ledge to snatch a gull out of mid-air; the lonely call of a Swift Fox searching for a mate on a cold prairie night. Many sights and sounds that almost disappeared from our wilderness are now more common, thanks to complex reintroduction efforts aimed at conserving biodiversity and restoring balance to human-affected ecosystems.

Not since dinosaurs became extinct 65 million years ago has earth experienced such ongoing biodiversity loss as it has in recent years. Although many factors are involved, the loss, deterioration and fragmentation of habitat due to human development tops the list. While putting programs in place to conserve wild populations is the first proactive line of defence against extinction, in many cases numbers are so low scientists have no choice but to initiate recoveries by moving survivors to better locations, or taking them into zoos and other facilities for captive breeding. Stock from these captive populations can then be used to try to re-establish a viable, free-ranging population in the wild.

Although the World Conservation Union lists 200 reintroduction projects currently under way around the world, re-establishing animals in their original habitat is more than a matter of simply setting them loose and hoping they will go forth and multiply. It is a complex, long-term effort that poses a raft of difficult economic, social, and environmental challenges.

To prevent disease spread, social disruption and the introduction of alien genes, most reintroductions take place in areas where no remnant population exists. Where possible, reintroduction candidates are of the same subspecies or race as the original, since they are more likely to possess genetic traits adapted to the habitat. If sufficient wild stock exists, and studies show that moving some will not be detrimental to the existing population, it is easier and less expensive to catch and relocate animals than to captive breed them, since they already have the skills needed to survive in the wild.



Extirpated in the Canadian Prairies by the 1930s, the Swift Fox now numbers some 300 animals in the wild. Photo: Lu Carbyn

Where numbers are insufficient, however, captive breeding may be the only option. One downside of this method is that, if few breeding pairs exist, the offspring produced will be from a very narrow gene pool — and may run the risk of magnified deficiencies. Fortunately, no such problems have been detected in captive-bred birds. Another is that captive breeding is costly. In addition to food, shelter and veterinary expenses, some species require artificial insemination or surrogate-type technologies to reproduce. Also, because most species of birds and mammals rely heavily on individual experience and learning as juveniles, they must be trained in essential skills. Success is more likely with captive-bred birds than mammals because avian behaviour tends to be more ingrained. At the same time, care must be taken not to get the animals too used to people, or they may invade human areas. Some degree of post-release care — including monitoring, supplementary feeding, veterinary care or predator control — may also be necessary, even over the long term.

Biologists with Environment Canada's Canadian Wildlife Service (CWS) are involved in several reintroduction efforts as members of multi-stakeholder recovery teams for species at risk. Their research contributes to an understanding of the causes behind a species' decline, the dynamics of its ecosystem, and its critical needs — including its required habitat, social behaviour, group composition, range size, shelter and food needs, and foraging and feeding behaviour. This kind of information is critical, because needs must be met, factors behind the

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decline minimized or removed, and the species protected over the long term across its entire range in order for the reintroduction to succeed.

When needs can't be met, such projects may have to be put on hold — as is the case with the Black-footed Ferret, a weasel-like mammal that was once common in the southwestern prairies and is no longer found in Canada. Although the ferrets have been captive bred in Canada using American stock, they can't be reintroduced here because there aren't sufficient populations of Black-tailed Prairie Dogs — the ferrets' main source of food — to support them.

A similar roadblock faces the Loggerhead Shrike, an endangered bird species whose population has dropped so dramatically in the last 25 years that an eastern subspecies now numbers 44 breeding pairs in the wild in Ontario and Manitoba. Although the loss of early successional grassland habitat is believed to be a major factor in the decline, information about other negative influences, including impacts along its yet-unknown migration routes and wintering grounds, is lacking. Therefore, first-generation birds from the existing captive breeding population won't be released into the wild until sufficient information is available and habitat recovery efforts have been initiated.

One of the greatest challenges in reintroducing Whooping Cranes to the wild is teaching them to migrate — a skill they would normally learn in the wild from their parents.
Photo: Geoffrey L. Holroyd

Another important element of any reintroduction is to ensure that the project is accepted and supported by the public, and by property owners and other stakeholders in particular. Since the support of landowners is essential to ensuring the long-term protection of habitat, endangered species management strategies must be understood and must incorporate other compatible land uses, where possible. If the species being introduced could pose a risk to property, these risks should be minimized and adequate provision made for compensation.

In Canada, support from ranchers has been integral to the successful reintroduction of the Swift Fox — North America's smallest wild dog — because uncultivated ranch land is the species' historic natural habitat. Once common in the dry grasslands between the southern Canadian prairies and Texas, the Swift Fox disappeared from the Canadian wilderness by the 1930s due to drought, loss of habitat, hunting, trapping, and the ingestion of poisons used for Coyotes and rodents. In 1972, an Alberta couple began captive-breeding the animals from American stock, and over the next 30 years more than 900 foxes were released into southern Alberta and Saskatchewan. Despite heavy predation by Coyotes and Golden Eagles, a steady supplement of new foxes, some translocated from the United States, enabled the species to become established. Today, the wild population in Canada numbers around 300 animals, 80 per cent of which were born in the wild.

An unusual situation exists with the endangered Vancouver Island Marmot, a small mammal that looks like a chocolate-brown groundhog. Although its ideal habitat still exists, the species has disappeared from two-thirds of its historic range over the past five decades, and now numbers fewer than two dozen animals in the wild because young marmots have taken to colonizing clearcuts instead of subalpine meadows. Clearcuts not only become unsuitable habitat as the forest regenerates, but also concentrate the marmot population, thereby making it more susceptible to predation.

While the birth of eight marmot pups in a zoo early this summer proved that the species will breed in an artificial environment, captive-bred marmots require a more natural setting to learn normal behaviours such as hibernation and fear of predators. To meet this need, a special breeding facility is being constructed on a mountain on Vancouver Island using funding from the provincial government, the forest industry and other private sources. The million-dollar facility will be operational by year's end, and the first marmots will be released in approximately three years. It is expected that the wild population will have to be supplemented with new members annually for 15 to 20 years.

Teaching wild behaviours to animals in captivity has been a focus of efforts to restore populations of endangered Whooping Cranes, which were down to only 16 birds in 1941 — all part of a wild flock that breeds in the Northwest Territories at Wood Buffalo National Park and winters on the Gulf of Mexico in Texas. In 1967, biologists began collecting eggs and establishing captive breeding populations, so that all of the nearly 400 Whooping Cranes that now exist are descended from three females in the original flock. To equip these captive-bred cranes with foraging skills — and to exercise their long, injury-prone legs — young birds are regularly walked through wetlands as they grow up. Even so, newly released whoopers are provided with supplementary food for their first few weeks in the wild. Juveniles are raised in pens beside adult whoopers, so they will follow the examples set by the older birds during nesting season, and handled by caretakers wearing crane

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puppets, so they won't imprint on humans.

In the past few years, 175 captive-bred cranes have been introduced to Florida to establish a new, non-migrating wild population. This flock, which now numbers about 73 birds, is still 25-percent shy of its target size — largely because captive-bred cranes are naïve and vulnerable to predation by Bobcats. The flock has since been moved to more open ranchland, where there is less cover for the Bobcats, and young captive-bred cranes are being taught to favour short grass and to roost on water.

Establishing a new migrating flock of Whooping Cranes is a bigger challenge, since the birds learn to migrate from their parents, and none of the captive-bred birds has the benefit of experience. Experiments using Sandhill Cranes from the American mid-west as surrogate parents met with some success, but resulted in a large number of birds being killed in powerline collisions. Imprinting on the Sandhill Cranes also disrupted the whoopers' courtship, so they didn't form pairs. Sights are now set on establishing a new wild migratory flock in the eastern United States — where it is not likely to come into contact with the original western flock — by using an ultralight aircraft to show them the way. Already used successfully with geese, the method will be tested this summer with Sandhill Cranes, and could be used for whoopers as early as next year. The privately funded effort will cost about US$750,000 per year for 10 years.

Lessons learned through centuries of falconry helped ensure the successful reintroduction of the Anatum Peregrine Falcon — a subspecies that had disappeared from most of eastern Canada, southern Alberta, Manitoba and the interior of British Columbia due to the widespread and intensive use of organochlorines, particularly the pesticide DDT. Over a 25-year period beginning in the early 1970s, Environment Canada produced 1 550 young falcons through captive breeding and sent them for release into wild and urban areas across the country. To prevent disease, the breeding facility was established at an isolated location in Alberta and raised its own quail as food for the young falcons. Although the captive-bred young learned on their own how to hunt and migrate, fresh meat was provided daily for up to two months after they were released. In several instances, persistent predators — such as Great Horned Owls and goshawks — were relocated to give the young falcons a chance to survive.

A special mountain-top breeding facility is under construction for Vancouver Island Marmots that will enable them to adapt more readily to the wild by exposing them to natural conditions.
Photo: Robert Milko

Today, anatum peregrines have been re-established in every geographic region of Canada that had them historically, except the Okanagan Valley of British Columbia, where a reintroduction effort is in its third year. With about 500 breeding pairs across the country, the species was downlisted in 1999 from nationally endangered to threatened. Captive-bred nestlings are still being added to some nests in Alberta and Ontario that have fewer than four young, to bolster the population.

Other factors have been a challenge in re-establishing Canada's largest living terrestrial mammal — the Wood Bison. Once more than 160 000 strong, Wood Bison roamed parts of British Columbia, Alberta, Saskatchewan, and the Northwest Territories before severe winters, wolf predation, hunting, and interbreeding with Plains Bison diminished their numbers. In 1957, a CWS biologist discovered a herd of 200 wood bison in a remote northwestern corner of Wood Buffalo National Park — the last of their kind. Disease hit the area, and in 1963 some members of the herd were transplanted to wild ranges in the Mackenzie Bison Sanctuary, Northwest Territories, and in 1965 others went to fenced ranges in Elk Island National Park, Alberta.

In 1969, the Wood Bison herd at Elk Island became infected with disease and had to be subjected to a severe test and slaughter program before it could be used to establish captive breeding herds in other locations. In 1975, biologists began transferring stock from the source herd at Elk Island for release in other areas to establish free-ranging populations in the wild. Their numbers grew so rapidly that, in 1987, the Wood Bison was downlisted from endangered to threatened, and captive breeding was discontinued three years later.

Today, recovery efforts have established six disease-free, free-ranging wild herds in Canada totalling 2 800 Wood Bison, and six disease-free captive herds totalling 700 more. Although Wood Bison are now found in all regions where they originally ranged, available historic habitat has been severely limited by the conversion of lands for agriculture and development, and the need to keep the Wood Bison geographically isolated from diseased herds and Plains Bison. To help achieve Canada's recovery goal of four geographically separate herds of 400 each, biologists are currently negotiating to expand their efforts into Alaska and parts of eastern Siberia.

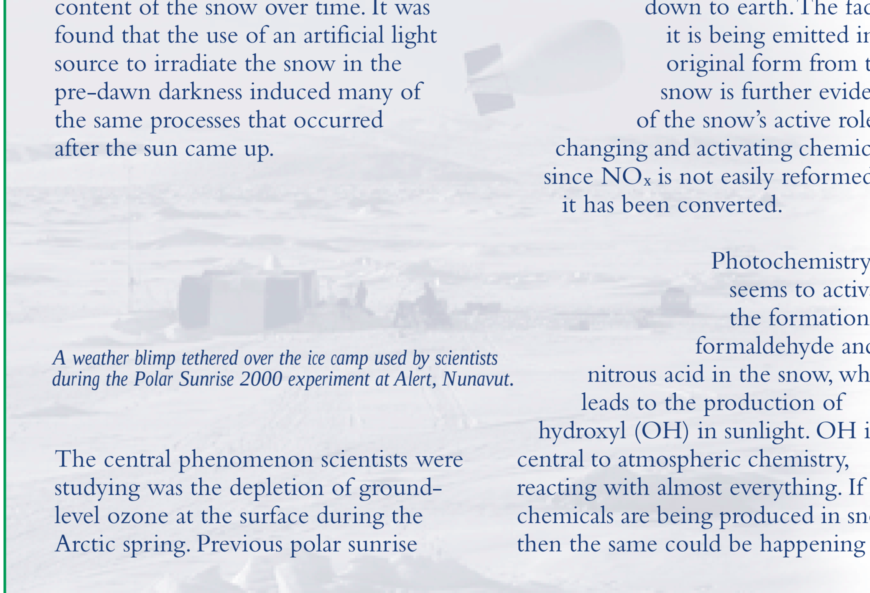
While proactive ecosystem-based conservation is the best method of managing wildlife over the long term, reintroduction efforts remain a crucial way of pulling species at risk back from the brink of extinction. Lessons learned as a result of the challenges posed by these and other projects will help to ensure that many of the birds and animals disappearing from our wilderness will once again call it home. S&E

SUNRISE SHEDS LIGHT ON POLAR CHEMISTRY

When the sun rises over the Arctic in March after nearly six months of darkness, its rays stir unexpected chemical reactions at the snow's surface. Driven by the release of compounds that have somehow been mobilized by the snow and ice, these reactions have likely been taking place since time began. However, it is only recently that scientists have begun studying them and the effects similar reactions in other snow-covered regions of the world could be having on global atmosphere and climate.

More than 30 scientists and university students from Canada, the United States, France, Italy, Germany and Japan were in Alert, Nunavut, from February to May 2000 to take part in the largest international study ever conducted of the photochemical effects of the polar sunrise. Some 15 scientists from Environment Canada's Meteorological Service of Canada were involved in the field campaign, which focused on ground-level ozone depletion and the potential role being played by chemical reactions in the snow pack and ice surface.

The long period of darkness leading up to the sunrise enabled scientists to monitor changes in the gaseous components of the air and snow before and after the event, using sophisticated methods such as mass spectrometry and laser-induced fluorescence. Thousands of other readings were taken of temperature and snow physics — including crystal shape, surface area, and air volume — and ice core samples were collected to further study changes in the chemical content of the snow over time. It was found that the use of an artificial light source to irradiate the snow in the pre-dawn darkness induced many of the same processes that occurred after the sun came up.



A weather blimp tethered over the ice camp used by scientists during the Polar Sunrise 2000 experiment at Alert, Nunavut.

The central phenomenon scientists were studying was the depletion of ground-level ozone at the surface during the Arctic spring. Previous polar sunrise experiments indicated that this is likely due to chemical reactions involving bromine. The fact that bromine is not normally reactive in the atmosphere points to the likelihood that it must somehow be transforming into an active state in the snow. Furthermore, recent satellite observations made over the region at the same time of year found increased levels of bromine oxide — a reactive form of bromine that is produced when bromine destroys ozone.

Scientists also found that mercury depletion in the atmosphere in the Arctic closely follows ozone depletion. This is of particular importance with regard to human and environmental health, as this toxic chemical may be falling back to earth and entering the food chain.

The expedition observed increased levels of nitrogen oxide (NO_x) being emitted from the snow after sunrise. NO_x is produced by the burning of fossil fuels, converted into other chemicals in the atmosphere, and eventually washed back down to earth. The fact that it is being emitted in its original form from the snow is further evidence of the snow's active role in changing and activating chemicals, since NO_x is not easily reformed once it has been converted.

Photochemistry also seems to activate the formation of formaldehyde and nitrous acid in the snow, which leads to the production of hydroxyl (OH) in sunlight. OH is central to atmospheric chemistry, reacting with almost everything. If these chemicals are being produced in snow, then the same could be happening in glaciers, ice caps and clouds — a phenomenon that could have wide-ranging implications.

The scientists involved in the experiment are spending this summer and fall analyzing and checking the quality of their data, and plan to present the results of their research at the American Geophysical Union conference in San Francisco, California, this December. In the meantime, plans are in the works for a follow-up expedition that would take place at least 100 kilometres north of Alert to minimize the impacts of the camp itself, and to more easily study the air over the Arctic ocean. Knowledge gained through these studies will add important dimensions to existing atmospheric models, and improve our ability to accurately predict the future state of our climate. S&E

Eminent Scientist Killed in Crash

It was with great sadness that *S&E Bulletin* learned of the death of one of the world's leading polar bear experts, Dr. Malcolm Ramsay, in a helicopter crash in the High Arctic on May 21. The 51-year-old biologist, who was a professor at the University of Saskatchewan, was conducting a ground-breaking study on the relationship between polar bears and seals when the accident occurred.

Dr. Ramsay worked closely with the Canadian Wildlife Service in Edmonton, and is remembered by his colleagues as a "true scientist", who was curious, widely read, and enthusiastic. In addition to his long-term research on the ecology and physiology of polar bears, Dr. Ramsay recently began a study of sharks off the Pacific Coast. He is survived by his wife, Susan Hatfield, and his two sons, Nicholas and Thomas.

CLAYOQUOT SOUND AN INTERNATIONAL TREASURE

Lush old-growth rainforests crowned by towering Sitka spruce, wild coastal beaches dotted with driftwood, remote alpine meadows, rich intertidal areas, salt marshes, mudflats and tangled networks of lakes and rivers make Clayoquot Sound one of the world's natural treasures. Long engulfed in land-use battles between loggers and environmentalists, the Sound is facing a more harmonious future with its recent designation as an international biosphere reserve.

Driftwood-strewn beaches are among the many unique habitats found in Clayoquot Sound.
Photo: Charles Ebbs

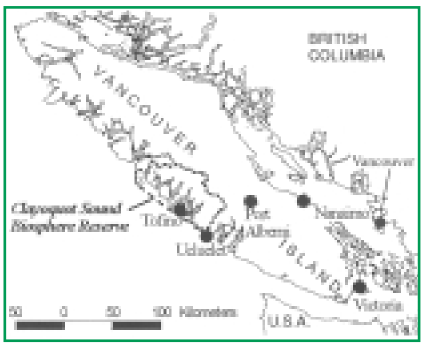
The title, bestowed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in May of this year, recognizes a shared commitment to balance environmental protection with the economic health of local communities. It is a major achievement for the Sound, which, just seven years ago, witnessed the largest act of civil disobedience in Canadian history over old-growth logging.

Three years ago, community leaders representing First Nations, the local municipalities of Tofino and Ucluelet, and the Alberni-Clayoquot Regional District decided to come together to ensure a sustainable future for the 4 500 residents of the region, and began seeking the UN designation. Their success resulted in the first UNESCO Biosphere Reserve in British Columbia, and only the eighth in Canada.

Located in the central-western region of Vancouver Island, about 250 kilometres northwest of Victoria, the new reserve encompasses an area of about 350 000 hectares that falls within the traditional territory of the Nuu-chah-nulth First Nations and includes the community of Tofino. The core protected area of the reserve links the interior mountains to the shore of the Pacific Ocean, and includes the Long Beach unit of Pacific Rim National Park Reserve and over 95 000 hectares of provincial parkland. In the remainder of the reserve, industries have agreed to take a selective and conservation-oriented approach to logging and economic development.

Science and Habitat Conservation

This is the third in a series of articles on the conservation of important habitats across Canada. In this issue we profile Vancouver Island's unique Clayoquot Sound region, which was designated a UNESCO Biosphere Reserve in May 2000.



Map of Vancouver Island showing the location of the Clayoquot Sound UNESCO Biosphere Reserve.

One of the things that makes the Sound unique is that it encompasses a vast range of habitats. As areas outside the reserve become progressively altered by human activity, the protection of these habitats is essential to the health of wildlife populations. The temperate rainforest of Pacific Rim is part of one of the highest biomass producing areas in the world, and a complex and ecologically significant ecosystem that supports a diversity of plant and animal species. Today, of the 170 major old-growth watersheds that once existed on Vancouver Island, only 11 remain — and eight of these are in Clayoquot Sound. Equally important are the shoreline habitats, mudflats and salt marshes that serve as resting and feeding places for the thousands of birds that stop at this crucial point on the Pacific flyway during their migratory journeys. The Sound's marine environment supports a wide variety of fish, and is home to seals, sea lions and humpback and other whales.

Currently the federal lead in this community-based effort, Environment Canada has been involved in extensive research on migratory and sea birds in Clayoquot Sound and other regions of Vancouver Island. Among these is the Marbled Murrelet, the only sea bird known to nest in old-growth forests. In addition, the Department provides funding and other support to efforts that contribute to the creation of a sustainable community.

The federal government has contributed $12 million to an endowment fund managed by the multi-stakeholder Clayoquot Biosphere Trust to support research, education and training that will help the region make the transition from a primarily resource-based economy to one that promotes sustainable economic development. S&E

NEW TECHNOLOGIES TURN OUT CLEANER DIRT

Fuel spills, mine tailings, smelting, and leaks from decaying batteries and other chemical-containing equipment have contaminated thousands of sites across Canada — lacing once-clean soil with toxic organic compounds and heavy metals. Scientists and engineers with Environment Canada's Environmental Technology Centre (ETC) and its alternative service contractor, SAIC Canada, are helping to develop speedier, more efficient ways to clean this soil and restore it to useable condition.

After more than four years of research and development, three new soil remediation techniques are moving toward full-scale field testing, and may reach the commercial market in a few years. These mobile technologies, some developed in collaboration with universities, are not only faster and more thorough than conventional methods for removing organic chemicals and/or heavy metals, but also have the potential to be less expensive.

The Membrane-Assisted Soil Leaching (MASL) process is designed to remove heavy metals, such as mercury, lead, arsenic, chromium, copper and cadmium, from sites contaminated by mining, smelting, old batteries, leaded fuels and other spills. The conventional way to extract these contaminants from soil is to leach them out with acid — a process that can slow down as the concentration of metals in the solution increases. MASL uses this same leaching method, but adds another step — membrane filtration to separate the heavy metal ions from the leachate. This enables the process to continue at acceptable rates, while unspent acid can be recovered for re-use in the process. The volume of liquid waste is reduced by 80-90 per cent and the metal-laden stream concentrated so that it is more economical to treat or dispose of, thereby resulting in cleaner soil than conventional leaching.

The CHELASOL process was originally developed to speed the preparation of lab samples for analysis by simultaneously separating the heavy metal and organic contaminants from soils. This new technology, which combines methods for removing the two types of contaminants in a single process, has also been evaluated for the remediation of contaminated soil. Potential applications are many, since nearly 40 per cent of contaminated sites in Canada are estimated to contain both heavy metal and organic contamination. With the CHELASOL process, acid is used to leach heavy metals out of the soil before a "chelant" (pronounced key-lant) is added that binds with the metal ions to form chelates. Solvent is then added to dissolve both the organic contaminants and the chelates, which are more soluble in the solvent than in water.

Dr. Andrew Daugulis, professor of chemical engineering at Queen's University, adjusts the parameters on a bench-scale Two-Phase Partitioning Bioreactor used to clean contaminated soil.

Tests show that CHELASOL performs as well as acid leaching in removing heavy metals from soil. CHELASOL was also able to extract nearly 80 per cent of polychlorinated biphenyls compared to only 55 per cent achieved through conventional solvent extraction. Removal levels for other organics, such as polycyclic aromatic hydrocarbons, were similar to those of the conventional extraction methods. Ninety-five to 100 per cent of the solvent used in the CHELASOL process can be recovered from the contaminated liquid through distillation, and heavy metals can be recovered by releasing them from the chelants and precipitating them out.

Scientists at SAIC Canada are also helping to take the Two-Phase Partitioning Bioreactor process, the brainchild of chemical engineers at Queen's University in Kingston, from the bench to the field, and then to the commercial market. Although bioreactors containing microbes are a fairly common way of destroying organic contaminants in soils, problems have occurred because concentrations of these contaminants

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must be high enough to sustain microbial growth but not so high that they kill the microbes. The new two-phase process gets around the problem by using a solvent to extract the organic contaminants, and then transferring the contaminated solvent to the bioreactor, where it forms an immiscible layer on the surface of a water/microbe mixture. Some of the contaminants in the solvent dissolve in the water until equilibrium occurs, and are broken down by the microbes. As this occurs, the equilibrium shifts and more contaminants transfer from the solvent phase, creating a self-regulating system that provides the microbes with only as much contamination as they can handle. Researchers at Queen's are using sophisticated software to determine the most effective combinations of microbes and solvents for the system.

Major steps for the future include moving all three technologies from batch to continuous processes that will take in contaminated soil at one end and produce uncontaminated soil at the other. SAIC Canada is currently looking for industrial partners interested in extending the techniques to field-scale, on-site demonstrations to further evaluate the systems before they can become commercially available. S&E

Groundwater Remediation with Vitamin B_{12}

Canadians are concerned about the quality of their water, and many depend on a clean supply of groundwater as their only source. Unfortunately, wells and aquifers can be easily contaminated by common groundwater pollutants such as chlorinated solvents — used in dry cleaning, degreasing, chemical processing, and paint stripping. Scientists at Environment Canada's National Water Research Institute (NWRI) have developed a method to decontaminate polluted groundwater while it is still underground using a mixture of non-toxic components.

Research at NWRI showed that a solution of vitamin B_{12} and titanium citrate injected into a laboratory model of an aquifer and well system effectively dechlorinated contaminants. Environment Canada patented this process and now the United States Army has commissioned a field demonstration at the Aberdeen Proving Grounds in Maryland, where groundwater was contaminated 40 years ago with a complex mixture of chlorinated methanes, ethanes, and ethenes that has not degraded over the years.

A recirculation and chemical-injection well at the site of the pilot-scale groundwater remediation study at the Aberdeen Proving Grounds.

The B_{12} solution is mixed on site and pumped into the contaminated groundwater by means of a recirculation well designed specifically for the site's hydrogeology and installed in the most contaminated area. Several multi-level monitoring wells, situated radially around the recirculation well, are sampled regularly to determine the effect of the treatment in the aquifer.

Results show that chlorinated methanes are degraded in minutes, and that chlorinated ethanes degrade more slowly, followed by biological degradation of second-generation products. Research is ongoing, but early results are encouraging. So far, researchers have found no accumulation of vinyl chloride, a carcinogenic chemical that may be produced when degradation occurs, and they have observed a prolific growth of bacteria in an area where nothing would grow before.

The field demonstration will continue until September, after which the U.S. Army will select the most effective remediation technology tested to treat the entire site. Meanwhile, NWRI researchers are continuing laboratory work to refine the process and solve any problems detected in the field. If all goes well, the new technology could help clean up numerous sites in Canada and abroad — particularly those contaminated with chlorinated solvents in concentrations high enough to be toxic to bacteria, and those needing rapid remediation.

TWISTIN' BY THE WHEAT POOL

Photo: Dan Newell

It emerges from behind a shroud of heavy rain against a sky as black as ink — a whirling, roaring vortex that stretches to the earth from the belly of a huge thundercloud, toppling buildings, uprooting trees and scattering cars as it cuts a swath of destruction through the landscape.

More tornadoes are reported in Canada than anywhere else in the world except the United States. The 80-odd twisters spotted here each year do tens of millions of dollars in property damage, and pose a risk to human life. According to scientists with Environment Canada's Meteorological Service of Canada (MSC), the frequency of these violent events could increase in the future as a result of climate change.

Sixty per cent of Canada's reported tornadoes take place in the southern portions of the prairie provinces of Manitoba, Saskatchewan and Alberta — one of two "tornado alleys" in Canada that also include the southwestern region of Ontario. While analyzing meteorological data on the two regions to determine trends in tornado frequency, MSC scientists noticed that springtime temperatures in the West were significantly warmer in the 1980s than the previous three decades, and that tornado reports also increased during this period. They also noted that tornadoes in the region were occurring, on average, 11 days earlier — suggesting that tornado frequency is physically related to mean monthly temperatures.

In general, tornado frequency increases in the spring and early summer with rising temperatures, then decreases in the late summer and fall as temperatures drop. Circulation models have predicted that mean monthly temperatures in the southern prairies will increase by two or more degrees with the doubling of atmospheric carbon dioxide levels due to greenhouse gas emissions. If this happens, the inference is that more western tornadoes will occur in the "shoulder" months of May, June, August and September as they become more like July — the peak month for tornadoes — and that the number of tornadoes in July will also rise as that month becomes warmer.

The exact cause and effect of this relationship is not clear, as tornadoes result from a combination of numerous complicated meteorological factors — some related to temperature and moisture, known as thermodynamics, and others to wind strength and direction, or dynamics. What we do know is that tornadoes form in severe thunderstorms that contain strong updrafts of warm, moist air that rotate as they rise. If the rotation grows sufficiently strong, the storm can evolve into a tornado.

We also know that thunderstorms form in unstable air masses, and that air masses become more unstable the warmer and more humid the atmosphere. Therefore, as temperatures rise, the thermodynamics become more favourable for creating thunderstorms and other extreme weather events. This theory was supported by a study on the possible effects of climate change on global lightning frequencies, in which scientists using a general circulation model found that a more unstable atmosphere (caused by a doubling of atmospheric carbon dioxide) resulted in a 40-per-cent increase in lightning frequency in continental areas, with western Canada being highly affected.

The more scientists learn about the complex connections between climate change and severe weather, the better able Canadians will be to prepare for and respond to the impacts of these events in the future. S&E

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SCIENCE AND THE ENVIRONMENT BULLETIN

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