S&E SCIENCE AND THE ENVIRONMENT BULLETIN S&E
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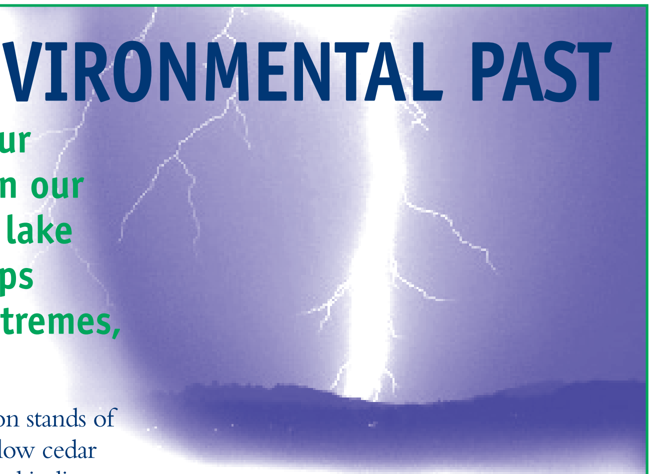
DECODING CANADA'S ENVIRONMENTAL PAST



Historical information locked in our biological environment is being used to learn more about past climatic events and trends.

A tremendous wealth of information about our biological and climatological past is locked in our environment. Everything from tree rings and lake sediments to insect fossils and glacial ice caps contains clues about historical trends and extremes, and how our ecosystems adapted to them.

Scientists are using these clues, along with human records such as aboriginal pictographs, Hudson's Bay Company reports and meteorological data, to predict the impacts of climate change in the coming millennium. Environment Canada is helping to solve the puzzle by bringing together Canadian and American experts from a wide range of disciplines to share their knowledge at an ongoing series of targeted workshops on Decoding Canada's Environmental Past.

These workshops focus on the use of *paleo*, or historical, human and natural records, to reconstruct variations in our climate and biodiversity during the last thousand years, and examine the different ways our environment has adapted or responded to these changes. Using major climate events as marker years to align their data, scientists from universities, museums and government agencies have issued surprisingly common messages about the impacts of climate change in Canada, where the effects of a changing climate are already being felt in many regions.

Tree rings are a rich source of paleo information, because ring growth is significantly influenced by climate. A recent study on Vancouver Island showed that 60 per cent of the ring-width variance in mountain hemlock could be attributed to climate variables in the previous year. High-elevation stands of mountain hemlock and yellow cedar have proven particularly good indicators, because the extreme nature of their environment makes them highly sensitive to climatic fluctuations. And, because many mature trees of both species exceed 500 years in age, they can yield long-term information. A study of old-growth mountain hemlock in Strathcona Provincial Park, on Vancouver Island, revealed a close correlation between significant intervals of reduced ring growth and the climatic episodes of the Little Ice Age, which reached its peak in the 18th to 19th centuries. These same periods coincided closely with significant moraine-building episodes and glacial advances.

SPECIAL INSERT SALUTING CITIZEN SCIENCE INSIDE!!

Another study of mountain hemlock growth trends and El Niño events on Vancouver Island since 1500 shows that periods of increased El Niño frequency generally correspond to intervals of enhanced ring-width growth. Hundred-and-fifty-year records from Saanich Inlet also suggest an increase in the frequency of strong El Niños in the future, and show a correlation between such events and outbreaks of the toxic aquatic organisms that cause red tides. Related to these increasing events is the recent discovery that shifts between climate states have occurred repeatedly and often abruptly in the past—most recently in 1976—with significant repercussions for fisheries, water resources, forestry, agriculture and habitats.

Both records of pollen ratios in lake sediment and tree-ring density in northwestern Canada between 1650 and 1990 show summer temperatures in the region on a gradual rise over the past four centuries. A comparison of these results with the reconstruction of white spruce establishment and mortality patterns at alpine treeline sites in the western Northwest Territories and central Yukon shows that the effects of this warming trend include a significant increase in tree population density, but only a minor advance in the treeline.

Tree-ring density records from northern Canada for the last 400 years indicate that devastatingly cold temperatures have been experienced in different regions of North America in the year following a major volcanic eruption—proof that

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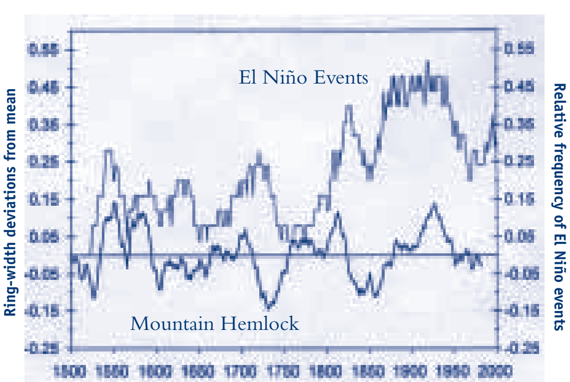
major events, even in other parts of the world, can have a profound impact on geographically distant environments. Because the sulphate aerosols emitted by volcanoes are similar to, but at much higher concentrations than, those released by many manmade sources today, increasing levels of pollution may have a similar cooling effect on future temperatures.

Lakes are also used to reconstruct past climate and biological changes. Studies in the southern prairies of Canada indicate that the most sensitive lakes display water-level changes that are broadly correlative with well-known hemispheric-scale climatic events. The abundance of pollen buried in lake sediments enables scientists to estimate climate changes, while pollen composition tells us how these changes have affected biodiversity. Synthesizing data from these sites can also suggest how atmospheric circulation has changed. Microscopic charcoal fragments in lake sediments can be used to reconstruct post-glacial fire incidence, and provide insight into changes in distribution, biodiversity and fire activity of forest ecosystems under a global warming scenario.

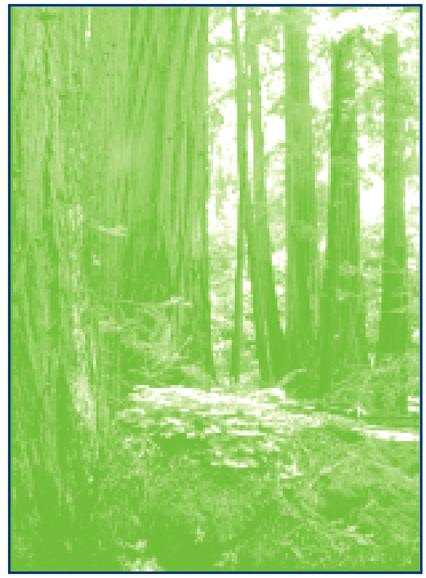
While ecosystem shifts tend to follow climate change, rather than precede it, insects serve as important "bell ringers" that forewarn us of changes to come. Fossils of aquatic midge larvae have recently been developed as quantitative indicators of past climatic changes, and provide a sensitive independent climate record for southern British Columbia. About 10 000 years ago, a sudden increase in the abundance of warm-water species was followed by a rapid 5^0C increase in summer temperatures. In the dry interior valleys of southern British Columbia, the immigration of salt lake species records the shift from a humid to a semi-arid climate.

Three different sets of data were used to examine past winter severity in the Great Plains region. Using aboriginal pictographic winter counts time-aligned by meteorological and pictographic evidence of a major meteor shower in 1833, researchers found that the length of time between severe winter episodes decreased between the 1680s and the 1880s, with bad winters especially prevalent during the 1800s. Studies of population density of white-tailed deer and pronghorn antelope on the margins of their ranges showed a close correlation between decreased numbers and severe winters, while bison remains reflected these seasonal stresses in tooth enamel formation.

Studies of climate signals locked in our environmental past also tell us how the impacts of human activities, combined with those of climate change, could affect our environment in the future. For example, the drastic human alteration of the prairie grasslands for agricultural purposes during the early part of this century combined with drought conditions to cause the catastrophic dust storms of the 1920s and 30s—with the insect populations still in a state of disequilibrium 60 years later. Had the biodiversity and root mass of the grassland ecosystem been left intact, they would have greatly reduced the impacts of this disaster, which resulted in billion-dollar losses to this dust-bowl region of Canada.



Graph showing the close correlation between El Niño events and the growth of mountain hemlock from 1500 to 2000.



Tree rings are a valuable indicator of how climatic conditions have changed over the lifespan of a tree.

Similar lessons emerge from human observation records of the flood and runoff histories of the Red River Basin from the late 18th century onward, which suggest that the Great Plains may have had a hydroclimatically wetter environment during much of the 19th century—when several major floods occurred in 1826 and 1852. Combining these data with geographical studies of the current flood plain—which has been dramatically altered by human development during the 20th century—indicates that if floods of this magnitude were to occur today, their effects would be even more devastating than those of the 1997 Red River flood. With severe weather events expected to increase as a result of climate change, the possibility of such a situation occurring is far from remote.

Understanding that natural atmospheric processes are ongoing and how they minimize or exacerbate the effects of human activities on the environment is essential to reducing our vulnerability to climate variability and change in the coming millennium. Next year's workshop, on integrated mapping, will add yet another chapter to our understanding of the correlation between climate and biodiversity, and further improve the effectiveness of our adaptation strategies. S&E

ROAD SALTS AN ENVIRONMENTAL CONCERN

Frigid temperatures and large volumes of ice and snow make winter driving conditions in many parts of Canada treacherously slippery. To help make travelling safer, an estimated 4 732 kilotonnes of road salt and calcium chloride are used to de-ice our highways each year. Unfortunately, salt-laden runoff from melting snow can contaminate small nearby lakes, streams and ponds, causing serious concerns over its impact on the plants and animals that live in these bodies of water.

The Rouge River Pond in Scarborough, Ontario.

While high levels of road salt have already been proven to have adverse effects on the health of aquatic organisms such as fish, much less is known about the impacts on the benthic, or bottom, layer of aquatic ecosystems. To learn more about this part of the aquatic environment, scientists at Environment Canada's National Water Research Institute in Burlington, Ontario, carried out a benthic study at the Rouge River detention pond in Scarborough, Ontario.

The Rouge River Pond receives runoff from a major multi-lane divided highway (the 401), another smaller highway, and a large urban catchment, and had been identified in previous studies as having elevated salt concentrations in its water column. Although the pond is an engineered structure designed to manage flow and treat stormwater, like many other ponds in urban areas it serves as important habitat for many species of plants, mammals, birds and amphibians.

To find out how elevated salt loadings affected the chemistry of the sediment porewater—the water that fills spaces between the solid sediment particles on the floor of the pond—and to identify impacts on benthic invertebrates, researchers gathered and analyzed samples of the porewater and carried out toxicity tests using a shrimp-like benthic invertebrate, *Hyalella azteca*.

Their results revealed that when salt-laden water enters a pond or lake it sinks to the bottom and prevents the normal water-mixing process, thereby depriving benthic organisms of a fresh supply of oxygen. The water within the sediments can also attain high concentrations of salt, which, in turn, increases the concentration of heavy metals, such as cadmium, in the porewater. Results of tests on *Hyalella azteca* showed that the porewater itself was highly toxic, and suggest that the toxicity was caused by metals rather than high levels of chloride.

Although much remains to be done to isolate the specific factors that contribute to porewater toxicity in small urban water bodies, the Rouge River Pond study is an important step toward determining the impacts of road salt on aquatic ecosystems most at risk. These findings are also an important contribution to the body of scientific work currently being carried out to determine whether or not road salts should be considered toxic substances under the Canadian Environmental Protection Act (CEPA).

Results of the CEPA assessment are scheduled for release for public comment in June, and the assessment is to be completed by the end of 2000. Should road salts be identified as toxic, discussions would then follow to identify appropriate measures to mitigate environmental risks, such as reduced usage or complete bans in highly sensitive ecosystem regions.

In order to maintain public safety levels on the nation's highways, Environment Canada is already working with Transport Canada and the provinces on road weather information systems—automatic weather stations that use specialized sensors embedded in the road to measure surface temperature, wetness and residual chemicals. Meteorologists use these data to produce pavement temperature forecasts which, in turn, enable road crews to better plan their winter maintenance operations. These techniques have been shown to increase the safety and efficiency of the road network, while at the same time reducing the use of de-icing chemicals. S&E

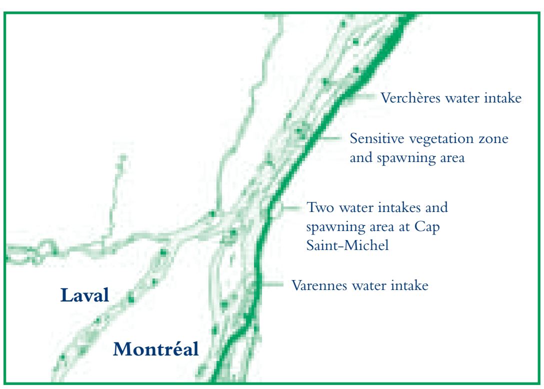
GENIE WORKS WONDERS FOR THE ENVIRONMENT

A state-of-the-art computer program that enables emergency responders to exchange information instantly and to create detailed site maps of environmental priority areas, weather conditions, forecasts of the movement of spilled oil, and other critical data is working wonders in the management of environmental emergencies.

Developed by Environment Canada scientists in Quebec, GENIE—Georeference Environmental Network for Information Exchange—uses the Internet to relay and synthesize a broad range of data that used to be sent by fax. GENIE's magic begins the moment Environment Canada receives news of an environmental emergency.

Data on the location of the incident, the type and quantity of pollutant involved, and other critical details are input into a computer and the resulting digital map is transmitted to the team of partners responsible for handling the emergency—including departmental experts on wildlife, weather and emergency services, Fisheries and Oceans Canada, the Canadian Coast Guard, and the Eastern Canada Response Corporation. Each partner adds a different layer of information, such as the location of water sources, nesting sites, wetlands and spawning grounds, river hydrodynamics, and forecasts of weather and the movement of spilled oil, and transmits it back. Within minutes, this input is synthesized and can be used to establish priorities and plans of action.

An oil-slicked beach.



GENIE map showing part of the St. Lawrence River near Montréal. The map combines information on the movement of a spill over time (indicated by dark band along the river) and sensitive environmental areas that could be affected.

GENIE has proven its worth in a variety of emergencies in Quebec over the past three years, from oil spills to train derailments. During the ice storm of January 1998, it even helped manage requests for help and offers of assistance received on a province-wide 1-800 telephone line. By using the program to correlate requests for shelter and fuel wood with forecasts of the time when electrical power was to be restored in different areas of the province, responders were able to direct resources to those who needed them most.

A constantly evolving tool, GENIE is undergoing several refinements at present, including the standardization of information exchanged among partners and the integration of existing georeferenced data within Environment Canada. Efforts are also under way to expand the number of partners who can be called upon in emergency situations, and to enable more people—including municipalities affected by an incident—to use the Internet to access this information directly.

Most importantly, GENIE's inventors are working closely with environmental emergency responders in other regions of the country to expand the use of this leading-edge technology across Canada—a prospect that will mean faster and more informed decision making in the coming century and help reduce the impact of ecological disasters. S&E

PORTABLE BURNER TO CLEAN CANADA'S ARCTIC

Leaking or corroded fuel containers are an environmental hazard in any region of the country, but pose a particularly serious threat in fragile ecosystems like the Arctic. Yet numerous drums of degraded diesel and other waste fuels once used to power generators, vehicles and other equipment on the North Warning System are stored in various remote locations throughout northern Canada.

How to safely dispose of this unusable or "off-specification" fuel—much of which has been contaminated by sediment and water—has proven a difficult challenge. Flying the heavy containers to a southern facility where their contents could be burned-off or "flared" at a high temperature would be a tremendous financial expense, and leaks in the aging containers could make transport difficult or dangerous.

The portable burner developed by Environmental Technology Centre staff to flare waste fuel stored in remote locations.

In searching for a solution to the problem, the Department of National Defence approached Environment Canada's Environmental Technology Centre (ETC) about the possibility of designing a burner that could flare the fuel on site. The ETC engineers had some difficult requirements to meet. First, because the sites involved were remote, the unit had to be portable by helicopter—a considerable feat, given that most industrial burners are very large, permanent pieces of equipment. Second, it had to be capable of burning-off about one barrel of fuel per hour, so that each job could be completed within a one-day shift, as the sites were no longer equipped for an overnight stay.

The designers came up with the concept for a dual unit, each burner consisting of a commercially available burner head and a refractory-lined stainless-steel drum. Each unit is designed to be flown to a site in pieces, and can be assembled in half an hour using basic hand tools. The unit looks like an elongated soup can about three metres long and more than a metre across, with a burner head at one end and a heat deflector at the other. The head, which was originally developed for use in boilers, shoots swirling flames into the burner to help break up water droplets and ensure the complete combustion of fuel that might not otherwise burn cleanly. This process, combined with the high heat reflected by its liner, results in fewer pollutants in the emissions.

The unit has already been tested at the ETC laboratory using both fresh diesel fuel and off-specification jet fuel from the nearby Ottawa International Airport. Emissions tests confirmed a smokeless, clean burn, with both carbon monoxide and nitrogen oxide emission levels comparably low for both fuels. The dual burner was recently shipped to a remote site in the Arctic, where it will be field tested next summer, when weather conditions are at their most favourable. If all goes as planned, the unit could be in full operation throughout the North soon after.

This state-of-the-art technology, developed using relatively inexpensive, off-the-shelf components, will help to reduce the threat of environmental contamination by enabling the safe and efficient clean-up of potentially hazardous fuel depots at remote sites in Arctic Canada, and perhaps elsewhere in the world. S&E

SNAKE CONSERVATION A SLIPPERY FEAT

Elusive and reclusive, they slither swiftly and silently through the undergrowth, virtually undetectable thanks to a low profile and clever camouflage. For Environment Canada scientists and others involved in snake research and recovery programs, the challenges lie not only in the difficulties of studying these cryptic creatures, but also in the battle against negative public perception.

Canada's largest snake—reaching lengths of up to 2.5 metres—the black rat snake is an excellent and frequent climber that generally inhabits upland areas.

Although rattlesnakes are the only venomous species in Canada, the fact of the matter is that many people don't like snakes—whether they're harmless or not. In fact, one of the reasons there are 10 species of snakes at risk in Canada is that most have been, and in many cases still are, persecuted by humans. The results of a recent survey of 2 000 Canadian and American students—presented at a symposium of the Canadian Amphibian and Reptile Conservation Network in Quebec City this October—showed that people develop an aversion to snakes at a young age.

Attempting to recover declining populations, therefore, means spending a great deal of time on public awareness and education aimed at cultivating an appreciation for the value of snakes and their roles in functioning ecosystems, and explaining that the gut reaction most people have toward snakes is likely a simple precautionary response retained from our evolutionary ancestors.

Even venomous species, like the threatened eastern massasauga rattlesnake, use their poison primarily for prey acquisition, and only secondarily for defence. To quell fears among people who live and work within its range—limited in Canada to Ontario's Georgian Bay and Bruce Peninsula regions and isolated populations in the Niagara Peninsula and the Windsor prairies—the massasauga recovery team has hosted numerous workshops and presentations instructing people on how to live safely with rattlesnakes in their environment. Although there is a lack of empirical evidence concerning the effectiveness of such initiatives, the steady increase in the number of massasauga sightings reported in recent years suggests that the more good information people have about these animals, the less they perceive them as a threat.

Development and land-use activities, however, remain the primary factors responsible for declining snake populations. In addition to causing direct deaths on roads, agricultural lands and residential properties, human activity and land conversion have greatly reduced and fragmented snake habitats, isolating populations and making them highly vulnerable to local extinction as a result. Yet learning more about their habitat needs has not been an easy chore, as snakes prefer to stay out of sight, are generally hard to locate and capture, and are therefore difficult to study—even in areas where they are plentiful. As such, traditional studies often yielded biased insights because they typically provided data only when and where biologists could actually observe snakes, and no information on snakes when they were out of sight.

It wasn't until the advent of small, temperature-sensitive, implantable radio transmitters that biologists were able to build up a bank of unbiased information on the activity patterns, habitat use, and thermal ecology of snakes. Among other things, they learned that snakes make more use of specific habitats, like forest edges, farmland hedgerows and hollow trees, than was previously thought. In addition, their choice of precise habitats is often driven by behavioural thermo-regulation, whereby they shuttle back and forth between different thermal environments in order to moderate their body temperature to facilitate their activity needs. Over time these data have revealed that selection of fine-scale micro-habitats within larger habitat contexts is of critical importance to snakes because they serve a variety of highly specific purposes—from prey acquisition and digestion to embryo development and hibernation.

Another useful advance in ecological studies of snakes has been the use of passive integrated transponders, or

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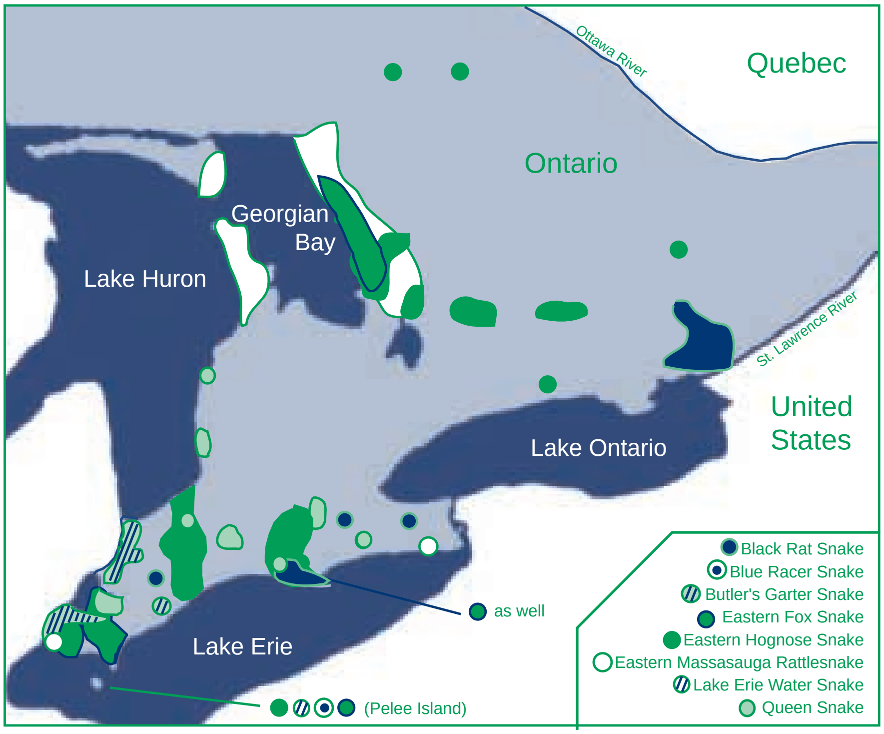

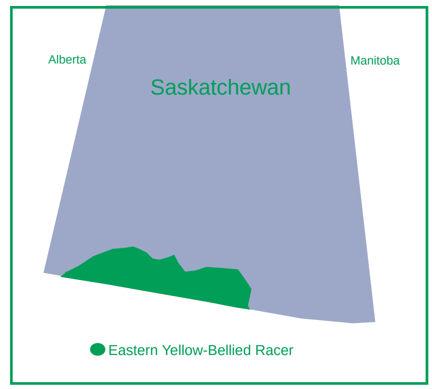

Maps of Ontario, British Columbia, and Saskatchewan showing the approximate ranges of the 10 snake species that are "at risk" in Canada.

PIT tags, to mark individuals and enumerate populations. PIT tags are inert glass beads, about the size of a grain of rice, that carry unique alphanumeric codes and are injected as permanent markers under the skin of a snake. These tags can be read in the field with a portable scanner, the identities of recaptured snakes being automatically stored, and later uploaded for use in demographic analyses. This simple technique is a vast improvement over previous external marking methods, which tended to fade and become indistinct over time. By using PIT tags, snake ecologists now have an unambiguous and highly efficient tool for quantifying large populations—a task that is particularly labour-intensive when working on communally hibernating species where numbers can exceed 100 snakes in a single underground den.

The most recent contribution to snake conservation comes from analyses of DNA and the quantification of the genetic population structure of snakes—a measure of how wild populations are organized and interact with one another. Canadian ecologists are responsible for the development of some of the first microsatellite genetic markers for snakes, in particular those used to carry out applied research on both the massasauga and the black rat snake—Canada's largest species, which often exceeds 1.3 metres in length. The reduction of deciduous forest has eliminated most of the black rat snake's original range, and this threatened species is now found in limited numbers only in the Carolinian forest region of southwestern Ontario and southeastern Ontario's Frontenac Axis.

To date these analyses have shown that black rat snakes have relatively large genetic neighbourhoods, with clusters of hibernating populations exhibiting little genetic differentiation. Massasaugas, in comparison, occupy extremely narrow genetic neighbourhoods—with a high degree of divergence between neighbouring populations living in relatively close proximity. This knowledge of the extreme genetic structure found in massasaugas has precipitated a new perspective on the species that has implications for the future direction of recovery and management. Among other things, the data suggest that while massasaugas may, in a sense, be genetically preadapted to living with relatively limited gene flow, they are also unlikely to naturally recolonize localities from which they have disappeared.

All of these tools are being used to gather baseline information on a small, isolated population of massasaugas persisting on a 230-hectare parcel of tallgrass prairie in Windsor, Ontario. In this case, the recovery team is using research evidence to assess the long-term viability of a population of snakes living in the very midst of an urban residential community, on land currently zoned for development. In a bid to recover this highly jeopardized population, the recovery team is drawing on insights from a variety of research perspectives, including behavioural ecology, vegetation management,

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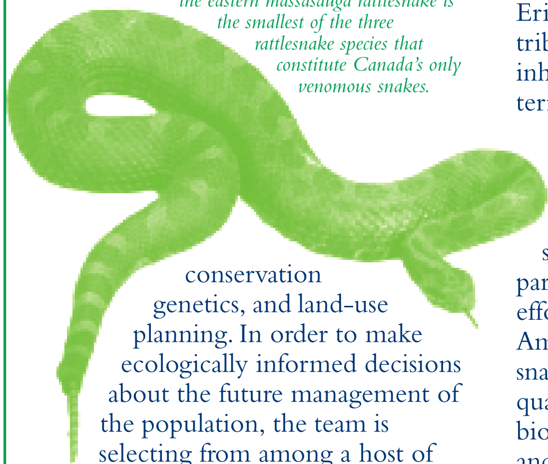

Rarely exceeding 75 centimetres in length, the eastern massasauga rattlesnake is the smallest of the three rattlesnake species that constitute Canada's only venomous snakes.

conservation genetics, and land-use planning. In order to make ecologically informed decisions about the future management of the population, the team is selecting from among a host of recovery options that range from in situ land stewardship to captive breeding and repatriation.

Last summer marked the start of an innovative snake recovery project that takes a "coarse-scale" ecosystem approach to the conservation of three species at risk on Pelee Island, in western Lake Erie. The project combines public awareness, community involvement, field ecology, ecotoxicology, genetic research, and geographic information system (GIS) mapping on the Lake Erie water snake, eastern fox snake and the blue racer snake, as well as assessments of the impacts of land-use planning and human activity on these species.

Found on only a handful of islands stretching between Point Pelee, Ontario, and Sandusky, Ohio, the endangered Lake Erie water snake is estimated to number fewer than 1 000 adults. An inhabitant of rocky shorelines, where it forages for fish and other aquatic prey, it is strongly affected by coastal development and is vulnerable to genetic swamping by the emigration of individuals from mainland subspecies. Studies of habitat use, availability, and the impact of toxic contaminants on this species are a major focus of the project being coordinated by the University of Guelph and the Canadian Wildlife Service.

The global distribution of the threatened eastern fox snake is restricted to the Lake Huron-Lake Erie waterway shoreline, adjacent tributaries and islands, where it inhabits primarily unforested, terrestrial shoreline ecosystems adjacent to marshes. The fact that this is one of the most seriously threatened natural regions of Canada and that 65-70% of the subspecies range is in Ontario lends particular importance to conservation efforts north of the Canadian/American border. To help the fox snake cope with declines in habitat quality and quantity, research biologists are mapping the movements and critical habitats of the island population and overlaying them with human activity and development patterns to identify areas of conflict and potential solutions. Furthermore, the team on Pelee Island has initiated the construction of artificial nesting and hibernation sites on protected lands—the former hollow logs filled with nesting material and shell remnants and the latter large excavated holes filled with loose material, such as rocks and sand.

Similar experimental efforts are being directed at the endangered blue racer, another communal nester and hibernator. Found in Canada only on Pelee Island, where its numbers are estimated at some 200 adults, the racer prefers savannah, prairie, and pasture habitats, and is negatively affected by certain agricultural practices and land conversion in general. Efforts to restore this species have also included the planting of hedgerows to provide safe movement corridors, prescribed burns to maintain open vegetation communities, and public outreach programs aimed at encouraging stewardship and the restoration of natural landscapes.

Despite the progress made toward conserving snakes in Canada over the past decade, much remains to be done for species currently at risk, as well as those approaching that status. By taking into consideration the impact and interaction of human activities on a suite of species across the landscape, the Pelee Island project serves as a model approach for future research—one that includes perspectives and skills from a wide range of disciplines and sectors, including educators, field biologists, planners, GIS technicians, government officials, molecular ecologists and local citizens. Its example could well hold the key to the success of future efforts to save these fascinating and ecologically mysterious creatures. S&E

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SCIENCE AND THE ENVIRONMENT BULLETIN

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Media representatives and others interested in conducting further research may obtain the names and phone numbers of departmental scientists involved in these and related initiatives by contacting the *Bulletin's* editor, Paul Hempel. He can be reached by e-mail at Paul.Hempel@ec.gc.ca, by telephone at (819) 994-7796, and by mail at Communications and Outreach Programs and Services, Environment Canada, 25th floor, 10 Wellington Street, Hull, Quebec K1A 0H3. Readers are welcome to e-mail or mail their comments and suggestions to the editor at these addresses.

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