S&E
SCIENCE AND THE ENVIRONMENT
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WOODSMOKE AND AIR POLLUTION

Sitting in front of a roaring fire on a chilly winter night may be romantic, but unless you have an advanced-combustion wood stove or fireplace insert, significant quantities of more than 100 pollutants associated with woodsmoke could be making their way into your home and the outside air. Several of these chemicals are carcinogenic, and linked with risks to human health and the environment.

The burning of residential fuel wood is an important source of air pollution in Canada, according to a 1995 emissions inventory released by Environment Canada and other members of a federal-provincial task force. The inventory shows that residential fuel wood combustion is responsible for about 25 per cent of fine particulates found in Canada's air pollution, 15 per cent of volatile organic compounds (VOCs), and 10 per cent of carbon monoxide.

Residential fuel wood combustion is a major source of fine particulate emissions in Quebec, the Atlantic provinces and the Northwest Territories. Ontario, Manitoba and British Columbia also receive significant volumes of air pollution from residential wood burning, which is a concern in many urban areas of the country where usage is concentrated. In mountainous regions of British Columbia, weather patterns exacerbate the problem by trapping smoke near ground level in populated valleys for extended periods of time.

Illustration: Alain Reno

How are these pollutants created? If you watch wood burn, you will see that flames appear over only a portion of the log, while smoke issues from different areas. This smoke is a complex mix of particulates and volatile incomplete combustion products that are being distilled out of the wood. These incomplete combustion products include volatile and semi-volatile organic compounds as well as carbon monoxide, polycyclic aromatic hydrocarbons (PAHs) and other toxic chemicals. Fine particulates can cause eye and throat irritations, headaches, allergies and aggravate cardio-respiratory problems.

In conventional fireplaces and wood stoves, large volumes of these unburned compounds are sent directly up the chimney and into the atmosphere. One way of minimizing emissions from wood burning is to maintain a healthy fire—with a chimney temperature of 150-200ºC considered optimum for combustion. Reducing the air flow by closing dampers or burning fresh wood with a high moisture content reduces the combustion temperature and greatly increases the formation of creosote and atmospheric pollutants. Dark or smelly smoke rising from a chimney is an indication that the fire is not hot enough, and is releasing large quantities of emissions.

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Environment Canada Environnement Canada
Canada

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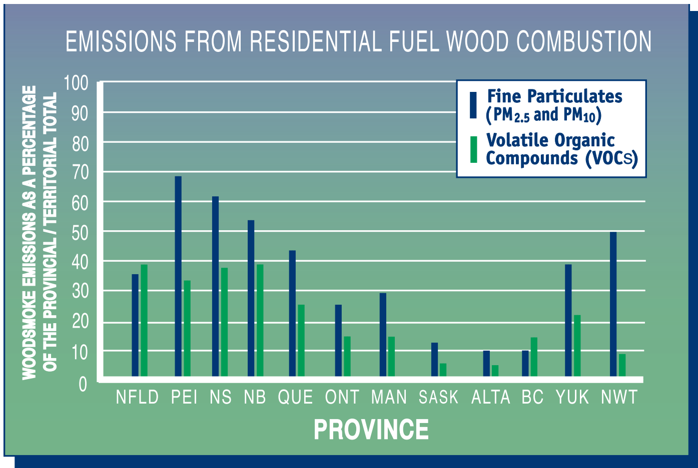
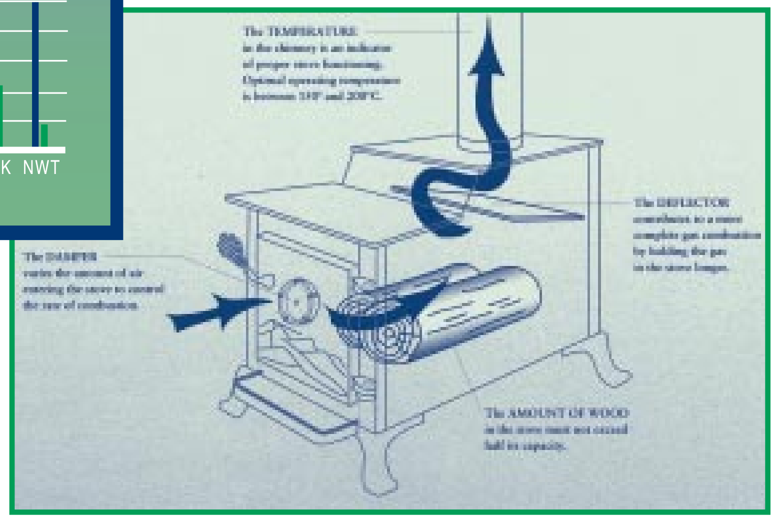


Key features of an advanced-combustion wood stove



An even more effective way to reduce pollutants is to use these clean burning practices with an advanced-combustion appliance. Such appliances have two simultaneous combustion zones—the first at wood level, where conventional burning takes place, and the second in the area immediately above, where volatiles are temporarily detained by a deflector and burned off before leaving the combustion chamber. Advanced-combustion wood stoves certified under Canadian Standards Association or United States Environmental Protection Agency performance standards reduce toxic emissions, emit 80-95 per cent fewer particulates, and are up to 20 per cent more fuel-efficient than conventional models.

Environment Canada has helped promote these technologies by providing support to change-out projects in communities in British Columbia, New Brunswick and Nova Scotia, where retailers provide people with financial incentives to swap their old wood-burning appliances for new, high-efficiency ones. Hundreds of households have made a switch as a result of these projects, which also included seminars and workshops on better burning techniques. A similar effort involving Environment Canada, the Hearth Products Association of Canada and several other organizations is currently running in Eastern Ontario.

The results of the 1995 emissions inventory will be helpful in making more accurate assessments of the environmental impacts of emissions from residential wood burning in Canada, and in assisting decision-makers in the development of guidelines aimed at reducing air pollution in the future. S&E

URBAN AIR QUALITY A BURNING ISSUE

Growing concerns over the health and environmental effects of wood burning in urban areas have prompted a four-month project to measure and analyze woodsmoke emissions in Montréal. The project, which is being carried out by Environment Canada scientists in cooperation with the Montréal Urban Community and the provincial public health department, is aimed at improving knowledge on the content and volume of woodsmoke emissions, determining local exposure to toxic pollutants, and identifying meteorological conditions that may exacerbate the problem.

Since December 1, 1998, monitoring equipment stationed at Rivière-des-Prairies, at the east end of Montréal Island, has been collecting data on particulate matter, polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds, as well as weather information such as wind speed and direction, temperature, humidity and visibility. So far, signals received from the site show large increases in emissions of particulate matter and PAHs after five o'clock in the evening. Since there is little vehicular traffic in the area, it is likely that the main source of these emissions is wood-burning appliances.

Scientists are planning to use the information gathered this season to develop a woodsmoke forecasting program that will enable them to warn citizens to minimize wood burning in conditions where air quality is seriously threatened.

MONITORING PROGRAMS TEACH CITIZENS TO SAFEGUARD HEALTH OF RIVER ECOSYSTEMS

Students, members of environmental organizations and other community volunteers in central British Columbia are helping scientists monitor the water quality of the Salmon River by collecting, identifying and counting insects, clams, crayfish, snails, leeches, worms and other tiny aquatic invertebrates that make the tributary their home.

This volunteer-based monitoring program—developed by scientists at Environment Canada's National Water Research Institute in Saskatoon in consultation with local groups and government agencies—enables people with little or no science background to take an active role in safeguarding their local environment by teaching them basic scientific sampling techniques. And it provides the scientific community with valuable information on how the river's ecosystem is changing over time.

Aquatic macroinvertebrates are prime subjects for such studies for several reasons. First, they are relatively easy to sample—not only because they are large enough to be seen without a microscope, but also because they are a primary food source for many important species of fish, and therefore abundant in most streams. Second, because they do not stray far during their lives, they indicate a river ecosystem's state of health by revealing the effects of short- and long-term environmental variations on local conditions.

Once the composition of the invertebrate community has been determined, inferences can be drawn about the health of the stream at the sites sampled and, ultimately, about the extent of habitat degradation caused by impacts such as organic enrichment or sedimentation. Some macroinvertebrates are more sensitive to water pollution or other habitat disturbances than others. However, understanding which types of pollutants are involved or why certain types of animals are present or absent requires more information than a simple count can provide.

A second aspect of the monitoring program involves measurements of key water quality variables and the sampling of algae. Once again, community volunteers are enlisted to take samples, but, in this case, professional laboratories perform the analysis. Often, this level of monitoring is carried out in partnership with government agencies, which use the information as an early warning of potential water pollution problems.

Volunteers collecting samples from the Salmon River, B.C.

Scientists working with communities to develop these programs are confident that these techniques can be applied elsewhere in the country and can play an important role in raising public awareness about pollution prevention and environmental stewardship. Researchers from the Institute are already providing hands-on training to and preparing an instruction manual for groups in Atlantic Canada, so that communities on the other side of the country will be able to participate in volunteer-based monitoring programs and become more aware of local water quality issues. **S&E**

TRACKING CANADA'S DEADLY STORMS

Tropical cyclones with winds that rotate at speeds of more than 103.6 kilometres per hour, hurricanes are devastatingly powerful storms that usually travel over a large area during their lifespan. As they make their way from Africa across the Atlantic Ocean to the east coast of North America and venture into the northern latitudes, they undergo significant behavioural changes—a phenomenon known as extra-tropical transition.

Meteorologists at the Canadian Hurricane Centre in Halifax, Nova Scotia, are on the leading edge of studies in extra-tropical transition, as well as in the danger that storm-induced waves and tides—known as "storm surges"—pose to coastal communities. They are using complex computer models and data from ships' logs, public archives and other historic records to diagnose these storms and better understand the physics that drives them. In January 1999, a scientist from China and a researcher from McGill University joined the team in Halifax to contribute their expertise to these studies for the next year.

What they have learned, so far, is that hurricanes move more like regular winter storms in northern latitudes than they do down south, where they tend to be more erratic. They also travel up to five times faster—a serious concern given the fact that a large number of small boats are on the water during the June-to-November hurricane season. While hurricane forecasting always requires extreme precision due to the concentrated impact of these storms, it is an even greater challenge in northern latitudes because effects vary from one side of a hurricane to the other—with stronger winds to the east and torrential rain to the west. It has also been found that, although hurricanes weaken as they pass over cooler waters, on rare occasions they interact with extra-tropical storm fronts and re-intensify. Hurricane Hazel, which caused 81 deaths and $100 million damage in southern Ontario in 1954, was such a hybrid.

Although few of the two or three hurricanes Canada's Atlantic provinces average per year make landfall, considerable damage has been caused in the past by torrential rains and high and forceful wind-driven waters that sweep the coastline where the eye of the storm approaches nearest. Pioneers in the study of storm surges, Environment Canada scientists have created the largest database on the subject on the Atlantic coast, using archival information and forecasts to identify areas that are most vulnerable to the effects of such a disaster. Water marks on buildings from the devastating Saxby Gale of 1869—the model of a worst-case scenario—indicate that ocean water levels reached two metres above the high-tide mark. With sea levels rising and storms becoming more intense due to climate change, scientists estimate that such a storm today would cause sea levels to rise nearly a metre higher—causing widespread and intense flooding in heavily populated coastal areas and on low-lying farmland.

In addition to sharing information with the international hurricane community through the committees of the World Weather Research Program and World Meteorological Organization, Canada's Atlantic meteorologists are helping to ensure public safety at home by working closely with the National Hurricane Centre in Miami, Florida, issuing technical and public bulletins, and assisting emergency responders in contingency planning. By encouraging land-use planners to consider this information when developing flood plans, managing dikes and building coastal infrastructure, science is helping to mitigate the future impacts of these deadly storms. **S&E**

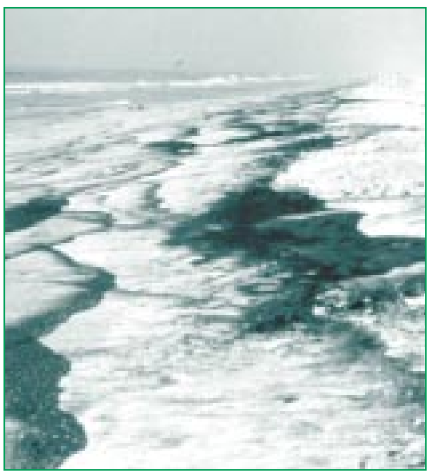
Typical path of hurricanes originating off the coast of Africa; the storms gather energy as they cross the warm waters of the Atlantic Ocean.

Above left: Hurricane Hortense made landfall in Nova Scotia on September 15, 1996.

SENSOR A REVOLUTION IN SPILL DETECTION

Detecting spilled oil that has washed up on a remote beach can be like finding a needle in a haystack. Because certain airborne sensors used to track spills have a narrow field of view, it can take hours of flight time to locate a spill and several more to carry out the physical inspection needed to verify sensing data. In difficult environments, such as in heavily weeded waters, along shorelines and in ice and snow, even the most advanced sensors have proven unreliable, leaving some spills undetected and sensitive environments and species at risk.

Beginning early this year, the world's most advanced system for detecting and classifying oil spills will begin operation aboard a DC-3 aircraft based in Ottawa. Developed with the help of a consortium of agencies that includes Environment Canada and the U.S. Minerals Management Service, the Scanning Laser Environmental Airborne Fluorosensor (SLEAF) is the first real-time sensor able to detect and classify oil in even the most difficult environments.

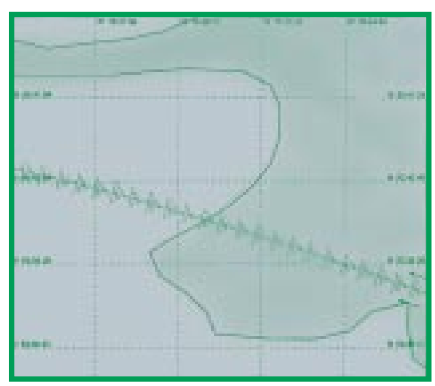


Narrow bands of oil at the high-tide line of a sandy beach

This sensor collects fluorescence data from various surfaces in the marine and terrestrial environment. It does this by shining a beam of ultraviolet light onto the surface of the Earth, causing certain compounds—including polycyclic aromatic hydrocarbons (PAHs) found in petroleum oils—to become excited and give off light in the form of fluorescence. Few other compounds in the environment show this tendency. In addition, different classes of oil fluoresce with different intensities and exhibit different spectral signatures, meaning that the bands of colour in each class's spectrum are unique.

SLEAF is the new generation of the Laser Environmental Airborne Fluorosensor (LEAF), which was developed in Canada in 1992. The main shortcoming of the original fluorosensor was that it illuminated an area only 10 centimetres wide and 30 centimetres long at an altitude of 100 metres, making it easy to miss spills on beaches and shorelines, where oil tends to pile up in a narrow band at the high-tide line. The new sensor is equipped with a high-powered laser strong enough to operate at an altitude of 600 metres—giving it a field of view six times as large as that of LEAF. One of two conical scanning mirrors is used to direct the laser beam in a circular pattern, enabling it to collect 400 samples per second in a swath up to 200 metres wide. Advanced detection and classification algorithms enable SLEAF to detect and classify contamination as light refined, crude or heavy refined oil, as well as estimate the percentage of oil coverage on either side of the flight path.

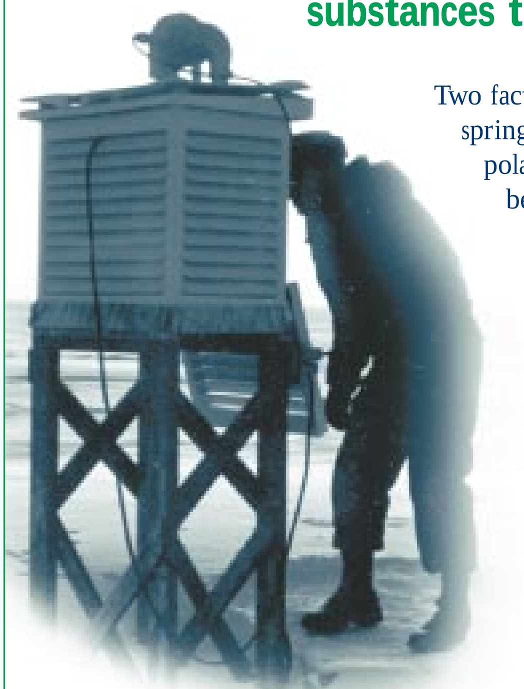
Factory acceptance tests conducted on the new scanning laser fluorosensor have proven the technology capable of detecting and classifying even minute quantities (only 0.5 per cent of the total area illuminated) of a weakly fluorescing oil on a sand background. Used properly, this kind of precise information will help to mitigate the potentially disastrous effects of an oil spill on sensitive marine and coastal environments by eliminating the need for costly and time-consuming physical inspections, and by directing responders to sites that require remediation. **S&E**



SLEAF survey charts will include surface features, latitude and longitude, and the survey track. The lines extending from each side of the survey track represent oil coverage detected.

CLIMATE CHANGE INCREASING OZONE LOSS IN THE ARCTIC STRATOSPHERE

Climate change may enhance the frequency and depth of severe stratospheric ozone loss in the Arctic and could delay the recovery of the Arctic ozone layer by a decade or more, according to an Environment Canada report that reviews recent science on the issue. Findings show the greenhouse gases that are warming the lower atmosphere are causing cooling in the Arctic stratosphere in spring—thereby promoting the formation of polar stratospheric clouds that allow ozone-destroying substances to cause more damage.



An EC scientist takes weather measurements at Alert, on the northeast tip of Ellesmere Island, NWT.

Two factors make ozone destruction in the polar regions brutally efficient during the spring. One is the polar vortex, a nearly closed circulation system that isolates the polar stratosphere from sunlight and the surrounding atmosphere, causing it to become extremely cold. At temperatures of -80ºC or lower, a second factor comes into play: the formation of polar stratospheric clouds. These frozen clouds cause ozone-depleting substances that are normally stable and therefore harmless to the ozone layer to break down into forms that are easily broken apart by solar radiation. With the return of sunlight in the spring, these unstable compounds release large volumes of chlorine and bromine—powerful ozone-depleting catalysts, each molecule of which can destroy thousands of ozone molecules before returning to the troposphere and being removed by other chemical reactions.

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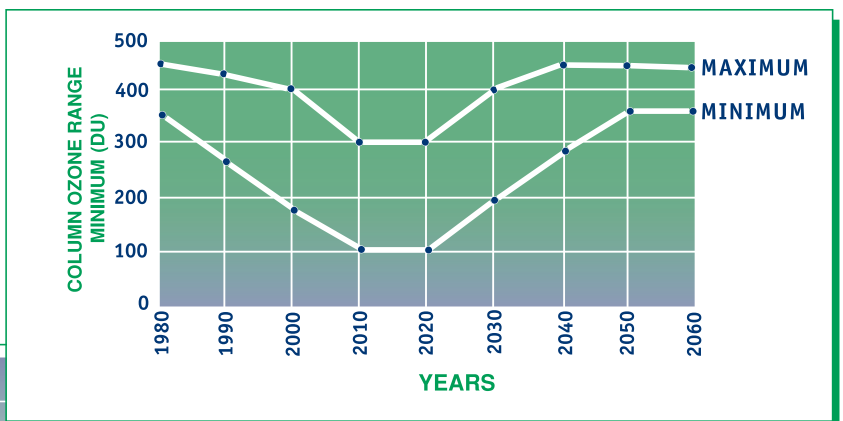
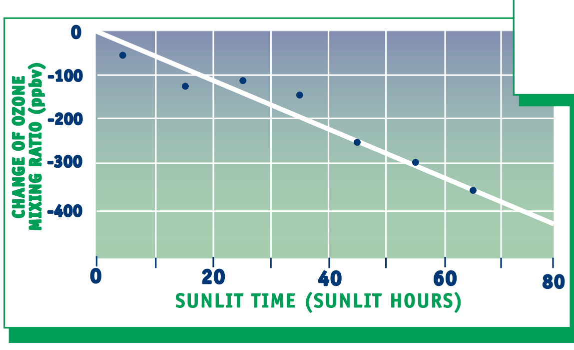


A computer model of the possible minimum and maximum Arctic ozone depletion until the year 2060 (Source: Arctic Ozone, *1998)*



Measurements of a single air mass as it moves around the Arctic vortex show how ozone concentrations decrease with accumulated exposure to sunlight, January 4 to February 9, 1992. (Source: Arctic Ozone, *1998)*

Stratospheric ozone observatory at Eureka, on the west coast of Ellesmere Island

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Most of the world's ozone is produced over the tropics, but it is distributed all over the world by winds. Ozone forms in the stratosphere when oxygen atoms liberated by powerful ultraviolet (UV) rays combine with intact oxygen molecules. It is gradually destroyed by sunlight and natural chemical reactions, but there is usually enough new ozone coming in to replenish losses. In recent years, excessive volumes of ozone-depleting substances released into the atmosphere by human activity have caused ozone depletion. In six out of the last nine years, unusually low ozone values have been observed over the Arctic during the spring with ozone losses of up to 45 per cent reported in 1997.

With lower stratospheric temperatures spurring the more frequent formation of these clouds and ozone-depleting industrial chemicals expected to be at or near peak levels for the next 10 to 20 years, the situation could worsen in the coming decades. Larger depletions in the ozone will expose highly sensitive Arctic lifeforms to significant increases in UV radiation from the sun, and could lead to reduced ozone levels over southern Canada as ozone is redistributed in the atmosphere.

Further monitoring and research on the Arctic ozone layer is necessary to understand trends and atmospheric processes. Climate change and ozone depletion should be treated not in isolation, but as interrelated parts of a common strategy for moderating the human impact on the atmosphere. S&E

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is a bi-monthly publication produced by Environment Canada to provide information on leading-edge environmental science and technology to Canadians.

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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 and by telephone at (819) 994-7796. Readers are welcome to e-mail their comments and suggestions to this same address.

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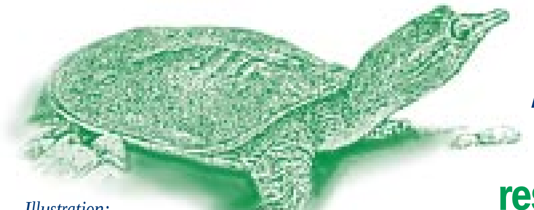

Illustration: Canadian Museum of Nature

A PLACE IN THE SUN

Reaching down through a wire cage, a field researcher carefully handles a newly hatched spiny softshell turtle. After its weight and other data have been noted, the hatchling gets a free ride to the next stage of its life—at the water's edge. If its habitat remains undisturbed, this turtle may live to adulthood. Many of its number, however, haven't been quite that fortunate.

Spiny softshells need sandy or gravelly shoreline for nesting, but also use the area—often a large rock—to take in the sun. This basking activity is important to researchers because it gives them an opportunity to observe the species more closely. Unfortunately, basking also attracts attention from boaters and cottagers, who may unintentionally disturb a nesting site.

Softshells use their tube-shaped snouts as snorkels, so they can breathe while under water.

The spiny softshell turtle was listed as a threatened species by the Committee on the Status of Endangered Wildlife in Canada in 1991. A recovery team, made up of scientists from Environment Canada, the Ontario Government and non-governmental organizations, began work a year later to stabilize and increase the size of the population. Although exact numbers are difficult to pinpoint, estimates put 500-1,000 softshells on the Sydenham and Thames rivers in southern Ontario and about the same number in other parts of the province, such as Long Point National Wildlife Area. The species has also been observed in the Ottawa River. Less than 100 are found in the Lake Champlain area of Quebec where recovery efforts are being carried out jointly with the United States.

While there is heavy predation of spiny softshell eggs and hatchlings by animals such as raccoons, foxes and coyotes, people are the most significant problem—with one-quarter of the nests at some sites lost due to human disturbance. To help make nesting more productive, recovery team workers install wire cages over the nests after they have been laid from mid-June to July. These cages help prevent interference until the hatchlings are born some time between late August and October.

When they hatch, the young are about the size of a two-dollar coin. The male of the species is olive brown with pronounced spots on its shell that are coloured a light tan in the centre. The female does not have such pronounced spotting, but is the larger of the two sexes, growing to slightly larger than a dinner plate—but just as flat. Although their shells are not really soft, they have a leathery feel and not the hard slick surface found on most other kinds of turtle shells.

As with many recovery efforts for species at risk, much of the initial work with the spiny softshell focuses on determining the full extent of its habitat, tracking its movement, gathering data on size and general health, and sharing information. So far, the recovery team involved has established that a large part of the threat to this species comes from a loss and degradation of nesting, basking and hibernation sites. Radio transmitters placed on turtles have shown that they can travel distances of up to 30 kilometres in a year, while some move less than half a kilometre. This suggests to researchers that, if all the right habitat elements are present, the turtles won't move far. Further radio tracking in future will help the recovery team determine where the turtles go for the winter, enabling further habitat protection of those areas.

Starting with the 1998 nesting season, the recovery team, in cooperation with Environment Canada, has begun studying the role contaminants might play in infertile eggs recovered from hatched or failed nests. In the meantime, efforts continue in working with landowners who have spiny softshells on their property, and in protecting and rehabilitating nesting sites as much as possible. So far, Ontario landowners have been very receptive to habitat protection—an important aspect of any effort to protect species at risk. **S&E**

Softshell hatchlings