S&E SCIENCE AND THE ENVIRONMENT BULLETIN S&E
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INDICATORS CHART HEALTH OF GREAT LAKES

The Peregrine Falcon is one of several bird species in the Great Lakes Basin whose population is bouncing back from the effects of environmental contamination.

Population growth and industrialization had a staggering impact on the aquatic and terrestrial environments of the Great Lakes Basin during the 20th century, compounding the effects of 250 years of human settlement. Home to one fifth of the world's fresh water, the region has seen its population swell to more than 33 million people, while its natural habitats and the number and diversity of native species have continued to shrink.

To determine the sources and effects of various stresses on the Great Lakes, and the effectiveness of current policies and programs in protecting and restoring this unique and valuable ecosystem, Environment Canada and its partners under the Great Lakes Water Quality Agreement have identified 80 indicators of environmental health—ranging from contaminant levels in Herring Gull eggs to native mussel populations. These indicators are grouped within seven environmental compartments: air, water, land, sediments, biota, fish and humans; as well as issue by issue. By analyzing a representative selection of these indicators, for which historical and current information was readily available, the third biennial *State of the Great Lakes—1999* report shows how the Great Lakes have changed over the past several decades.

Concentrations of many contaminants are on the decline.

While the report suggests little change over the two years since the previous report, it reveals several longer-term trends. One of these is a steady decline over the past 20 years in the concentrations of many key pollutants in the environment—likely due to banning and restrictions on their use. This has led to declines in levels of these contaminants in human tissues, with composite levels of seven persistent organochlorine pesticides in human breast milk decreasing by 80 per cent since 1975.

Several other environmental indicators reflect this trend, including levels of contaminants in fish tissue, which have been gradually declining for more than a decade. Fish tissue samples show concentrations of the banned pesticide DDT declining at a rate consistent with that of the early 1970s, but mercury concentrations seem to be fluctuating around 1980s levels. Total concentrations of polychlorinated biphenyls (PCBs) have also declined over the last two decades throughout the Lakes. Despite progress, however, concentrations of some contaminants are sufficiently high that fish consumption advisories remain in place for all five Great Lakes.

Contaminant concentrations in most colonial-nesting, fish-eating birds are also significantly lower than they were 25 years ago, and are currently at levels where gross ecological effects are no longer apparent. Measurements of organochlorine compounds (e.g., DDT, PCBs and some metals) in Herring Gull eggs indicate that most contaminants at most sites are continuing to decline at a rate similar to that over the last couple of decades, and that differences among sites are not as dramatic as they once were.

Air sampling indicates that concentrations of the organochlorine lindane have increased in precipitation in recent years, and may continue to do so due to increased applications of the pesticide throughout North America. Concentrations of dieldrin, on the other hand, have decreased overall. Despite 54-per-cent and 30-per-cent decreases in sulphur dioxide emissions

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in Canada and the United States, respectively, rain is still acidic throughout most of the Great Lakes region, where it affects inland lakes. Emissions are expected to remain at approximately current levels for the next 10 years, making it unlikely that the situation will improve in the near future.

The area and quality of coastal wetlands are decreasing.

Terrestrial habitats are also feeling the stresses of human impact. The lands within about a kilometre of the shoreline are not only ideal for diverse plant and animal communities, but also a focal point for human settlement, industry and recreation. To accommodate human needs, we are destroying, degrading, fragmenting or otherwise altering this habitat. These activities have a profound impact on the lakeshore's natural communities.

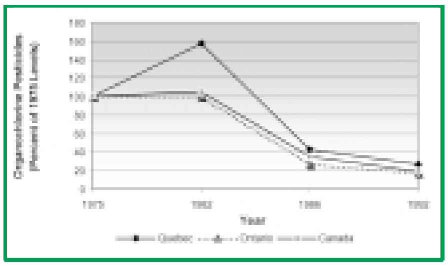
The total coastal wetland area is decreasing within the Basin, and the quality of remaining wetlands is being affected by added sediment loads caused mainly by activities such as agriculture, construction and logging. These loads can bury submergent vegetation and affect fish spawning and other functions, as well as carry high quantities of nutrients, pesticides and other chemicals. Loads in the St. Clair River area are relatively high compared to other Great Lakes wetland watersheds, mainly due to intensive agricultural activity.

At the same time, farmers are adopting more sustainable agricultural practices. Since 1993, almost 8 000 Ontario farmers have had Environmental Farm Plans approved that identify areas of concern on their land and the actions they will take to remediate them. Industries have also taken steps to reduce pollutant loads into the Great Lakes, with open-water concentrations of phosphorus relatively stable since the mid-1980s and, in most cases, at or below proposed targets.

Remedial Action Plans for 42 Great Lakes Areas of Concern continue to be developed and implemented, including a recent effort at Cootes Paradise Marsh near Hamilton, Ontario. By reducing local point-source pollution and creating a barrier to prevent large carp from entering the marsh, more than 200 hectares of vegetation have already been restored, including wild celery, which has been absent from the area for 50 years. Other benefits have included improved water quality and the return of various bird and frog species.

Several bird species are staging a comeback.

One of the most important regions in North America for many species of birds, the Great Lakes Basin is witnessing the comeback of several once-threatened species. In the past, Peregrine Falcon populations were severely reduced by DDT contamination, which weakened the shells of their eggs and, therefore, lowered their hatching success. Annual Breeding Bird Surveys indicate that efforts to restore their populations through the release of hundreds of pairs of peregrines over the past 20 years are paying off. Now, the species' status in Canada has been upgraded from endangered to threatened



Graph showing aggregate mean concentrations of seven organochlorine pesticides in human breast milk for Ontario, Quebec and Canada, expressed as a percentage of 1975 levels.

nationally. Last August, the peregrine became the first bird to be removed from the endangered species list in the United States.

Giant Canada Goose populations, once thought to be extinct, have exploded since the 1980s, and the species is now considered a nuisance in parts of the region. Regulatory agencies are raising hunting limits to control numbers, while others are involved in capture and relocation projects.

Near extinction in the 1970s due to toxic chemicals, the Double-Crested Cormorant has also staged a dramatic comeback, increasing its population 300-fold over the past three decades to 38 000 pairs. More numerous in the Great Lakes than at any time in its recorded history, the species' impact on fish populations is now being studied.

On the flip side, populations of some wetland-nesting birds, including the American Bittern and the Black Tern, are declining—possibly due to the loss of coastal wetland habitat. The tern, whose population has dropped 75 per cent since 1966, may also be suffering from the continued use of DDT on its wintering grounds in Latin America.

Exotic species continue to stress the ecosystem.

Significant decreases in the number of sea lamprey—a non-native, eel-like species that feeds on other fish—have occurred in most areas of the Great Lakes since control measures were implemented in the early to mid-1960s. However, studies in the Great Lakes Basin show that other exotic species remain a major stress to the ecosystem. They can cause drastic changes to the food web and the cycling of contaminants, as well as declines in the diversity and density of native populations.

The accidental introduction of the zebra mussel has severely reduced native clam populations, and could eliminate them completely in some areas within four or five years if the zebra mussel's population continues to grow at its current, rapid rate. The round goby, a non-native fish species whose population is expected to grow and expand, could also pose a threat to the biological community of the Lakes. Several other exotic species that have been discovered in some lakes—including the spiny waterflea and the rusty crayfish—could pose as yet undiscovered problems if they continue to spread.

By including analyses of a greater number of environmental indicators and adding data to the current list, the next State of the Great Lakes report, due out in 2001, will provide an even more complete picture of the way in which the Great Lakes ecosystem is responding to human influences—both good and bad. S&E

MISSILE SITES TARGETTED FOR CLEAN-UP

Once known as the bread basket of the Soviet Union, the Ukraine's agricultural land has been subjected to extensive environmental contamination since the Second World War—from toxic spills at abandoned missile sites to hazardous waste from mining activities. To address concerns over the potential health risks posed by these sites and to encourage global clean-up efforts, Environment Canada recently completed a training and technology transfer project aimed at enabling the former Soviet republic to return this land to arable use.

The four-year, $5.7-million project was funded by the Canadian International Development Agency and involved Environment Canada's Environmental Technology Centre (ETC) and two private-sector engineering consulting companies. Ukrainian partners included the national Ministry of Defence, Ministry of Nuclear and Environmental Safety, and Academy of Sciences.

The project took place near the central Ukraine cities of Khmelnitsky and Pervomaisk at two of the 176 intercontinental ballistic missile system silo sites that are located across the country. The sites and their surrounding facilities underwent complete assessments and were used to demonstrate a variety of cost-efficient and broad-application techniques for remediating soil and groundwater contaminated with diesel fuel, lubricants, heavy metals, rocket propellants and other toxic substances.

Location in the Ukraine of the two missile sites where the technology transfer project took place.

Twenty-three Ukrainian engineers, chemists and technicians spent up to a year in Canada undergoing extensive classroom training at the ETC in Ottawa and at private consultants' facilities in Toronto, as well as attending hands-on demonstrations at remediation sites in central Canada. In addition to receiving instruction on the basics of project management, sampling, monitoring, clean-up techniques, field and laboratory analytical methods, safety, and environmental philosophy, they had to learn two new languages: English and computer-ese.

After Canadian training was completed, half a dozen ETC scientists went to the Ukraine for one- to three-month field sessions to set up equipment and demonstrate site assessment and remediation techniques. They established a full-scale analytical laboratory at a university in Kiev, and set up a mobile soil-washing station to demonstrate the removal of hydrocarbons and metals from contaminated soil. Drum skimmers, which are commonly used in oil spills, were used to remove crude oil from the surface of ponds and creeks. Hydrocarbon-impacted groundwater was extracted using skimmer pumps and

A skimmer being used to recover oil from a creek at one of the contaminated Ukrainian sites.

then heated to remove contaminants through a process called steam stripping.

Less capital-intensive bioremediation technologies were also employed, including bio-piles and landfarming—both of which involve constructing containment cells to prevent pollutants from leaching into the surrounding environment, and then working nutrients and water into the contaminated soil to stimulate the growth of hydrocarbon-destroying bacteria.

After the project was completed, a seminar was held so trainees could make presentations on what they had learned to their colleagues and other guests. In the months since, Kharkov military university, where the analytical equipment is now located, has also launched an environmental training program. Both steps offer promise for the transfer of this technological know-how to other parts of the country and beyond its borders. S&E

GLACIERS AND CLIMATE CHANGE

The Canadian Rocky Mountains attract hundreds of thousands of visitors each year. Most are tourists, drawn by the spectacular beauty of alpine glaciers and icefields, but others are federal government scientists who have come to investigate the links between glaciers, climate, and Canada's water resources.

Peyto Glacier, located along the continental divide between Alberta and Bristish Columbia. The moraines and trimlines evident in the photo indicate that the glacier has retreated some two kilometres since the end of the Little Ice Age (c. 1850).

Photo: W. E. S. Henoch

Glaciers are an important part of the Canadian landscape. Canada's surface terrain has been defined by a million years of glacier and ice-sheet fluctuations, and today only Antarctica and Greenland have more glacier ice. Glaciers have much to tell us about past and present environmental conditions. Analysis of ice cores taken from glaciers reveals a layer-by-layer record of past temperatures, pollution levels, and atmospheric conditions. This information about past climates helps researchers understand variations in today's climate, and predict the effects of changes in the future.

In certain parts of the country, glaciers play a key role in supplying communities with water for irrigation, drinking, and hydro-electric power. The runoff they provide is essential also for maintaining river and riparian habitat. Concern is growing about the impact that changes in glaciers may have on water resources in western Canada. To learn more about what those impacts might be, scientists at Environment Canada's National Water Research Institute (NWRI) in Saskatoon have been working with colleagues from Natural Resources Canada to study the Saskatchewan-Nelson River Basin in the Canadian Rockies.

The eastern slopes of the Rocky Mountains have approximately 1 300 glaciers, which, by many estimates, have lost 25-75 per cent of their mass since the peak of the Little Ice Age, around 1850. Researchers compared fluctuations in glacier mass in the last century with modern fluctuations to determine if there is a recognizable pattern or trend in the volume of water released by glaciers over this period. Past fluctuations were reconstructed from old maps, photographs, analysis of direct measurements, and data on glacier form and composition. Modern fluctuations were determined using remote-sensing data, measurements of mass balance, and data from the Canadian Glacier Inventory at the NWRI.

It had been thought that climate warming would cause an increase in melt-water from glaciers in the short to medium term. Instead, scientists found that a pronounced reduction in the area of glacier-cover over the last 50 years has already led to reduced yields of water during critical periods in the highly glacierized sub-basins of the Saskatchewan-Nelson River Basin. One critical period is from August to December each year, when a diminished water supply would not only hamper hydro-power operations, but would also affect the spawning of several species of fish, including the endangered Bull Trout. To build on

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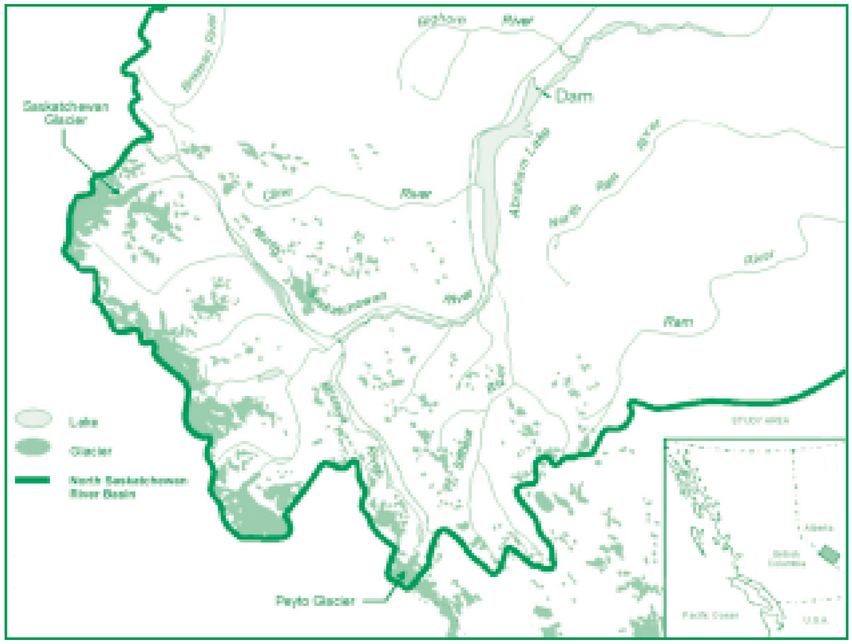
these results, the researchers are now planning a more extensive study of all the major contributing basins of the Rocky Mountain eastern slopes.

NWRI scientists are also part of a research team investigating the impacts of climate change on the glacier reserves feeding the Columbia River, a system that runs through British Columbia, Washington and Oregon, and supports an extensive complex of hydro-electric developments. Their first step is to determine changes in glacier resources since 1850 and compare these with historical changes in climate. Using an atmospheric-hydrologic model, researchers will then try to predict how these reserves will respond to climatic variations in the future—information that will assist resource managers in maximizing power production and minimizing downstream hydrologic and ecological impacts.



The eastern-flowing rivers of the North Saskatchewan Basin, showing glacier coverage.

Environment Canada and Natural Resources Canada have recently amalgamated their glacier science expertise in a National Glaciology Program. The new program will improve our understanding of how Canada's water resources are responding to climate change, enable us to develop adaptive strategies for managing these resources, and provide better information on the movement, deposition and volume of pollution in our environment. S&E

EFFECTS OF CLIMATE CHANGE COULD SNOWBALL IN MOUNTAINOUS REGIONS

From space, the bright white patches of snow and ice in earth's polar regions and mountain chains shine like beacons in the darkness, their brilliant surfaces reflecting the sun's energy. This process acts as a global air conditioner, keeping the surface temperature of the planet in balance.

According to recent studies by Environment Canada scientists, warming trends caused by climate change could have a dramatic effect on these regions. If atmospheric levels of greenhouse gases continue to rise, experts say global average temperatures may increase 3-5°C. In snow-covered mountainous regions, warmer temperatures will melt snow, reduce the reflective snow cover, and allow more solar energy to be absorbed by the earth's surface. As surface temperatures heat up, they will cause even more melting and, consequently, even warmer surface temperatures—a circular chain of events known as "positive feedback."

This cycle could have a dramatic effect in mountainous regions of British Columbia. Higher temperatures and less snow could upset sensitive ecosystems, allowing trees and other vegetation to invade open areas that are essential habitat for certain species of wildlife, and could leave some ski areas in the Rockies and southern B.C. without enough snow to operate. They could also have a significant negative impact on water resources, which rely heavily on snow melt, particularly in the mid to late summer. Domestic water supplies could be hit hard, as could migrating salmon if water temperatures become too warm.

ICING RESEARCH MAKING SKIES SAFER

Although a ground-level de-icing is standard procedure at airports, hazardous conditions can occur when severe icing takes place in flight.

Aircraft icing has caused two major airplane disasters in North America in the past five years. Although most planes are designed to withstand routine icing, hazardous conditions occur when they encounter large, supercooled drops, which freeze on contact and can jam control mechanisms, decrease lift and cause stalling.

Environment Canada scientists have conducted dozens of flights into winter storms on the East Coast and over the Great Lakes to learn more about what causes icing, and to find better ways of predicting hazardous icing conditions. Considered among the top groups in the world in their field, they were one of the first to extensively document from the air the microphysical characteristics of freezing precipitation. This information is being used to improve forecasting and should lead to better engineering standards for aircraft certification.

Research flights have taken place over St. John's, Newfoundland, and the Great Lakes—icing-prone regions of the country that receive an average of 150 and 75 hours of freezing precipitation per year, respectively. Special instruments on board the aircraft collect data on the microphysical parameters of the clouds, including pressure, temperature, horizontal winds, altitude, liquid water and ice content, and droplet size and concentration. Scientists use these data to develop statistical probabilities for worst-case icing scenarios in different conditions, and to assess the accuracy of numerical forecast models.

It is only recently that these computer models have been able to predict such parameters as liquid water and ice content, and most are still unable to forecast droplet size. These parameters are important in determining icing severity, because the higher the liquid water content of a cloud and the larger the size of its droplets, the more likely these droplets are to collide with and, therefore, freeze to the hard surface of a plane. Small cloud droplets—less than 30 microns (30 millionths of a metre) in diameter—are less likely to collide with an aircraft surface because they are lighter and tend to follow the air flow around the plane. Larger drops, such as freezing drizzle (100-500 microns) or freezing rain (500-3 000 microns), are more likely to collide because of their greater momentum.

In addition to characterizing icing environments, scientists are studying the way freezing precipitation forms. The classical method, which can be fairly accurately predicted, is for ice crystals or snowflakes to fall through a warm layer of air, melt, and then supercool to sub-freezing temperatures as they pass through a colder layer near the ground.

Environment Canada scientists focused on a second formation method while conducting research flights near St. John's, where 75 per cent of freezing precipitation forms as a result of supercooled cloud droplets growing from condensation and collision with other droplets. This non-classical or "collision-coalescence" method is of particular concern because it produces large precipitation that collides efficiently, and cannot yet be predicted by numerical models. However, the data from these research flights are being used to develop a new numerical forecast model that will be able to predict these non-classical cases explicitly.

Environment Canada, in partnership with the National Research Council of Canada, Transport Canada, the National Aeronautics and Space Administration, the U.S. Federal Aviation Administration and others, is currently involved in a study to assess the usefulness of remote-sensing instruments, such as radars, satellites and microwave radiometers, in determining aircraft icing conditions aloft. This real-time information would be invaluable in informing pilots of conditions at takeoff and landing, when most icing-related accidents occur, and would also improve the accuracy of long-term forecasts.

As a follow-up to this work, the Department is proposing the development of a prototype aircraft-icing detection/warning system that would integrate data from a variety of sources to generate detailed warnings for hazardous icing conditions both on the ground and in the air. Such a system would be a major step forward in making air travel safer in Canada's severe winter climate. S&E

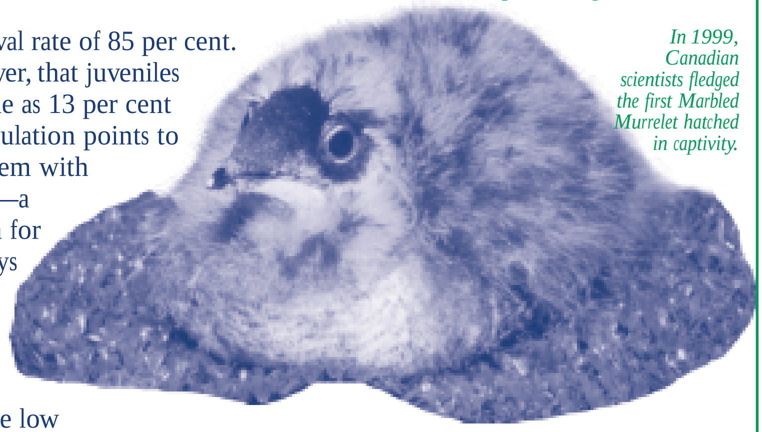
THE MYSTERY OF THE MARBLED MURRELET

Ground-breaking research is shedding some light on the private life of the Marbled Murrelet—a squat, robin-sized seabird whose nesting habits have remained a mystery to ornithologists until recent years. Since 1998, Environment Canada biologists have successfully radio-tracked this threatened species to its nesting sites, and fledged the first murrelet chick ever hatched in captivity.

Departmental scientists have been studying murrelets since 1990, three years before the first active nest in Canada was found in an old-growth forest on the coast of British Columbia. The discovery was a surprise, since most alcids, like puffins and guillemots, nest on steep cliffs or in crevices or burrows; and 1 000 metres above sea level, high on the mossy side-branch of an ancient cedar, seemed an unlikely place to find a seabird. Although the nest of a Russian murrelet was found in 1961, the first one in North America didn't come to light until 1974. The birds are notoriously hard to spot en route to their nests because most of their trips are made in the dark, and daylight excursions to carry small fish to the nestling are unpredictable and uncommon.

Concerned about declining numbers of this once-common species across its range—limited in North America to the Pacific Coast between California and Alaska, and in Canada to the coastal region of British Columbia—Environment Canada and its partners at Simon Fraser University and the B.C. Ministry of Forests launched a large-scale banding program in 1994. Researchers have captured and banded some 1 500 birds in the Desolation Sound area and other parts of the B.C. coast over the past six years.

Their research showed that murrelets can live 10 years or more and that, despite the direct impacts of oil spills and gill-netting, and displacement from old-growth forests due to logging and from coastal waters due to aquaculture and marinas, they have an annual survival rate of 85 per cent. The fact, however, that juveniles comprise as little as 13 per cent of the total population points to a possible problem with nesting success—a serious concern for a species that lays only one egg a year.



In 1999, Canadian scientists fledged the first Marbled Murrelet hatched in captivity.

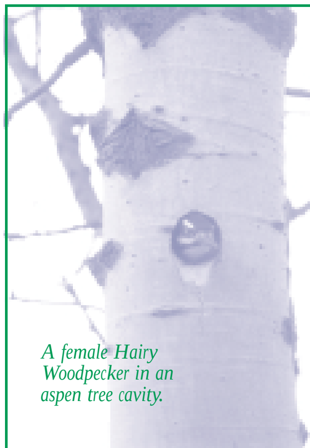
Scientists theorize that the low juvenile recruitment rate may be related to a shortage of suitable nesting habitat brought on by the disappearance of old-growth forests. These have been reduced to roughly half their historical coverage and are shrinking rapidly due to extensive logging. With less prime habitat to choose from, murrelets may be nesting in unsuitable areas, where their eggs are more prone to predation or exposed to the effects of weather.

To determine the precise habitat needs of the species, researchers used the "occupied detection" method of watching and listening for murrelets and assuming that if they were below the forest canopy or circling they had nests nearby. Although these studies showed old-growth forests in valleys as primary nesting habitat, scientists are now realizing that the data may have been skewed by the facts that these areas are more accessible for field work than others, and that many birds use valleys as transportation corridors.

In 1998, biologists found evidence to support this theory after birds fitted with radio transmitters led them to 23 nests—most located on steep slopes in high-altitude forests and most of these completely inaccessible to humans. The same held true last year, when another 46 nests were found in similar circumstances. These discoveries could have a significant impact on habitat conservation efforts, which are currently centred on low-altitude old-growth forests.

Last spring, radio tagging also resulted in two murrelets laying eggs in a research boat while they were being fitted with transmitters. This chance occurrence resulted in one of the eggs being hatched, and the fledged chick released back into the wild. The experience could prove useful if there is ever a need to create a captive population, as no captured murrelet has ever survived in captivity.

This spring, scientists will expand their radio tracking efforts to include Clayoquot Sound. They hope, by identifying and protecting the optimum habitat required by this mysterious bird, to ensure not only its survival, but also the survival of the many other species that rely on these increasingly rare ecosystems. S&E



A female Hairy Woodpecker in an aspen tree cavity.

WOODPECKERS MAIN THREAD IN NEST WEB

The lion may be king of the jungle, but in the mature mixed forests of British Columbia's interior, woodpeckers rule the roost. A recent study by Environment Canada biologists shows that half the forest fauna in the region nest in tree holes, most of which have been excavated by these primary cavity nesters.

The study shows that two species of woodpecker and one species of tree are the main threads in a complex "nest web" that connects the diverse members of the cavity-nesting community. Of the eight woodpecker species found in the region, the Northern Flicker and the Red-Naped Sapsucker excavate 75 per cent of the cavities used by all species, and 90 per cent of those used by secondary cavity-nesting birds, which cannot create their own. Ninety-five per cent of the cavity nests found over the course of the study were in trembling aspen, a broad-leafed deciduous tree.

These findings confirm woodpeckers as critical to the composition and function of the entire forest ecosystem. Their nesting holes not only support 19 species of secondary cavity nesters—including ducks, songbirds and owls—but are also sometimes used by weak primary cavity nesters such as chickadees and nuthatches, which sometimes create their own holes, and by mammals such as bats and squirrels. Their feeding habits also provide other woodland species with access to food resources such as sap, beetles, ants and grubs. Woodpeckers are also important predators of bark beetles and other wood-boring insects that cause significant tree mortality.

The strong dependency of cavity-nesting species on woodpeckers makes it critical that the kind of habitat required by this keystone group be preserved. In addition to showing a strong need for trembling aspen for nesting, woodpeckers also spend 75 per cent of their foraging time in conifers. In both cases, they are highly dependent on old or dead trees with characteristic defects such as a broken top, sloughing bark, or the presence of decay, fungal infection or wood-boring insects.

While such trees are abundant in unmanaged mature forests, they are rare or absent in managed younger forests, where they are often removed as useless or dangerous to workers. Planted stands are less likely to contain the diversity of habitat features required by woodpeckers because they are often similar in age, size and species composition. In northern Europe, large-scale declines in woodpecker populations and other native wildlife have occurred where timber farms have replaced vast areas of once-natural boreal forest.

Environment Canada is involved in several studies in the B.C. interior to investigate habitat requirements and develop forest management guidelines for the conservation of these critical habitats. Recommendations to forest managers include leaving all dead trees standing where they pose no hazard to people or property, and retaining a mixture of mature healthy, diseased and dead deciduous and coniferous trees.

The Department is also continuing its work in the central interior of the province, where it is using experimental cut plots, in cooperation with forest companies, to test how nest-web structure shifts in response to different forest-cutting regimes. It is hoped that, through these tests, selective harvesting methods will be developed that will retain the full complement of native wildlife and ecological functions in B.C.'s forest ecosystems. S&E

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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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