10. Environment



With populations exploding and economies expanding, humanity faces a number of pressing environmental challenges in the 21st century. Our thirst for oil and other fossil fuels has rapidly depleted supplies of these finite resources, and the pollution that results from consuming them is choking the air of the world's most populous cities and slowly warming the planet. Meanwhile, the Earth's rich biodiversity is dwindling at an alarming rate as rainforests are threatened and growing numbers of species become endangered by human development. Indeed, the global environmental picture is a troubled one.

The good news is that with growing awareness of the myriad environmental problems come efforts to find innovative ways to assess and combat environmental degradation, many of which rely on information technology (IT). It would be hyperbole to say that IT is the solution to the world's environmental problems, but IT is dramatically enhancing scientists' understanding of the environment and helping to ameliorate our impact on the planet's delicate ecosystems.

As it is in many aspects of life, IT is reshaping our understanding of the natural environment and humanity's impact on it, while at the same time helping to mitigate the associated problems. From advanced, efficient recycling programs to sensor networks to gauge the impact of human-produced carbon dioxide to DNA analysis to save endangered species, IT has become a critical piece of many attempts to address today's pressing environmental issues.

Creating a Cleaner World: Pollution and Waste Mitigation

By enabling sophisticated technologies to address air and water pollution, understand global warming and aquatic ecosystems, and facilitate recycling, IT is creating a cleaner, more sustainable world. IT is critical to many of the technologies being employed to counter humanity's growing ecological footprint.

Addressing Air Pollution

Air pollution levels have generally declined in advanced industrialized nations, but they remain a problem, particularly for some pollutants. Moreover, air pollution levels are worsening in many developing nations that are beginning to industrialize.

Scientists increasingly rely on IT-enabled tools to understand and tackle pollution. IT is central to the development of new tools enabling advanced monitoring of air pollution, including tracking and managing its sources and understanding better its impacts and how to mitigate them. Thus, for example, sophisticated computer models allow researchers to predict local atmospheric pollution levels in order to impose effective controls.

To study and alleviate smog in large cities, scientists can now deploy sensor networks to determine when and where pollution is worst, as well to ascertain the immediate causes of the pollution. Understanding the particular mix of causes of pollution in turn allows decisionmakers to evaluate cost-effective and feasible solutions. One example of IT-driven pollution monitoring involves the work of a team of Massachusetts Institute of Technology (MIT) scientists in Mexico City. With some of the worst pollution in the world, Mexico City exceeds the limit for acceptable air pollution close to 300 days a year. To address the problem, the MIT scientists used IT instruments to measure real-time pollution levels throughout the city, including a van equipped with global positioning system (GPS) and advanced pollution-detection equipment to measure neighborhood pollution levels, as well as to follow various vehicles, tracking their emissions.[1] From their extensive measurements, the MIT scientists have constructed advanced computer models to reflect more accurately Mexico City's pollution and give policymakers better tools to address the problem.

Harvard University and BBN Technologies have similarly installed over 100 wireless sensors on streetlights to collect data on pollution and weather factors at the city-block level throughout the city of Cambridge, Massachusetts.[2] This project—called CitySense—will offer scientists more precise measurements of weather phenomena, including how pollution from various sources disperses throughout the city. The CitySense system circumvents the battery life issues that such wireless networks typical face because the sensors draw electricity from the city's streetlights. In addition to supporting long-term environmental experiments to learn about mi-

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croclimates within the city, the CitySense project will serve as an "open laboratory," allowing researchers from around the world to access the project's data online and run research experiments using the network of nodes.[3]

Elsewhere, researchers using satellite data from the National Oceanic and Atmospheric Administration (NOAA) are tracking ozone, a critical ingredient in smog. Ozone, which can form when fossil fuel pollution reacts with sunlight, absorbs specific wavelengths of light and can therefore be detected by satellite imaging. Ozone shows up as a precursor to smog, so the new tracking tool allows researchers to anticipate ozone and smog, resulting in better pollution modeling and improved health advisories.[4] It is conceivable that one day a GPS-based fee per miles traveled system will replace the gas tax. Such a system would allow fees for travel to be increased on days health officials predict high local levels of pollutants, so as to give travelers incentives to drive less.

Yet another example of the application of IT to pollution tracking is the Vulcan Project. With funding from NASA and the U.S. Department of Energy, researchers from Purdue University, Colorado State, and Lawrence Berkeley National Labs have built a new, interactive mapping program—the Vulcan Project—that uses data collected by the U.S. Environmental Protection Agency and U.S. Department of Energy, among others, to pinpoint and quantify sources of carbon emissions in the United States.[5] By showing carbon dioxide emissions at a local level throughout the United States on an hourly basis, the Vulcan Project offers information on such emissions that are 100 times more detailed than was previously available.[6] In addition to tracking pollution sources by economic subsector and fuel type, the project supports advanced atmospheric modeling of pollution over time.

The Hestia Project, another project now under way, sets out to do worldwide what the Vulcan Project has done for tracking carbon emissions in the United States. The precise tracking and mapping of carbon emissions being done by the Vulcan and Hestia projects are important not just for understanding emission sources and geographic concentrations but also because they provide the critical information that underpins carbon-trading schemes.

Although the Vulcan Project is an important resource for the scientific and policy communities, there is another tool that offers the general public an easily accessible glimpse at the pollution in one's neighborhood. This tool—called MapEcos—is a relatively simple application that uses Google Maps to highlight, with color-coded points, data from the U.S. Environmental Protection Agency on toxic emissions from industrial sources. MapEcos reveals information about specific polluters (e.g., type of toxic emissions emitted by a particular business and how that entity's emissions compare with other businesses in the industry, county, state, and country) and offers links for obtaining more information.[7] Tools like MapEcos are but one example of the way in which IT is dramatically changing the information landscape for the public—organizing and making available useful information that empowers citizens to make informed decisions.

Understanding Global Warming

Global warming has emerged as a threat of the first magnitude, and IT is enabling better, more timely measurement of climate changes around the world. The Earth's atmosphere is a remarkably complex system, so modeling future temperatures requires the sort of complex calculations only made possible by high-powered computing. A better understanding of the nature of global warming enables policymakers to take measures to mitigate global warming—or failing those, to prepare for the harmful worldwide effects of global warming, such as rising sea levels and more severe weather events.

Scientists have enlisted a wide range of IT tools in their attempts to gain a better understanding both of the processes contributing to a warming Earth and of the extent to which the climate has changed. Such tools include extensive sensor networks to collect readings, as well as airplanes equipped with advanced data measurement instruments for collecting measurements in the upper atmosphere. A plane being deployed in the arctic by National Oceanic and Atmospheric Administration researchers, for example, has 30 airborne sensors that collect data that can be used to produce a detailed simulation of the chain of chemical reactions that arctic pollution causes and that increase ice melting.[8] For collecting critical data underneath enormous icebergs

in Greenland, the National Research Council of Canada has begun using an autonomous unmanned submarine that avoids the danger of sending humans into an area where splintering and crashing ice could spell death at any moment.[9] This submarine collects data on how quickly the ice in Greenland is melting, information that will be valuable in computer simulations to forecast glacial melting and improve understanding of how quickly sea levels will rise.

Though the specific efforts just described are very important, the real promise for the future lies with an integrated, worldwide sensor network currently under development—namely, the Global Earth Observation System of Systems (GEOSS). The GEOSS network is an international effort involving over 70 countries that will collect data pertaining not only to a changing climate but also to air quality more generally. By integrating worldwide data from satellite observations, ground-based sensors, and other sources, including mobile ones, scientists will be able to cull data to develop computer simulations that model atmospheric conditions—including weather, pollution from forest fires, and future global warming—more accurately than ever before.[10] And indeed if an integrated, worldwide sensor network had ubiquitous sensors—perhaps by being installed on vehicles (with the owners' permission) and transmitted wirelessly—it would not be unrealistic to imagine the creation of a national or even international real-time air pollution map.

Another area where computer modeling is playing an important role is in improving our understanding of the potential adverse effects of global warming. Bangladesh, for example, has begun developing maps that identify areas of the country on a precise scale that will be most vulnerable to severe droughts, storms, and flooding in a warmer world, so that the country can begin preparing for these events.[11] In addition, Internet users around the world can now go online and see virtual maps showing how rising sea levels may affect their local communities or how global warming is impacting glaciers.[12]

Researchers are also using soil-erosion models based on a geographic information system (GIS) to predict the effects of global warming on crop yields worldwide.[13] Although traditional crop surveys use questionnaires distributed to farmers to develop estimates of crop yields, global warming has increased the volatility and dynamism of crop yields. In 2007, the U.S. Department of Agriculture overestimated its annual national corn yield prediction by 200 million bushels; other analysts, who used GIS and weather forecasts to collect hundreds of gigabytes of data and then create digital soil maps, predicted the harvest correctly.

IT does not offer a panacea for global warming, but understanding the phenomenon of global warming would be nearly impossible without the tools that IT offers researchers. And as described below, IT will play a role in solving global warming by shifting the energy system to become less carbon-intensive.

Addressing Water Pollution

Water pollution—the contamination of bodies of water such as lakes, rivers, oceans, and groundwater caused by human activities—is a serious problem. Though water covers 71 percent of the Earth's surface, drinking water is relatively scarce. The potable water found in lakes, rivers, and in the ground accounts for only 0.65 percent of the total water on earth. Moreover, aquatic ecosystems are thoroughly interconnected (all rivers eventually flow to the oceans, etc.), and pollution in one place can have wide-ranging effects far beyond the immediate source.

IT has become an indispensable tool in understanding and managing water pollution. Most developed nations strictly regulate "point sources" of water pollution, such as contaminated discharge from a factory or sewage treatment plant into a river, but identifying and regulating "nonpoint sources" of water pollution is much more challenging. Nonpoint source pollution is caused when stormwater runoff picks up pollutants such as herbicides, fertilizers, grease, pet waste, and toxic chemicals from the ground, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. States report that nonpoint source pollution is the leading remaining cause of water pollution.[14]

Because the sources of nonpoint source pollution are widely dispersed and varied, cookie-cutter approaches to managing the problem that do not address the unique needs of a particular area are likely to be ineffective. What is needed are site-specific management approaches—which can range from

creating ponds near construction sites to corralling polluted runoff to placing gravel and sand in areas in order to sift out pollutants.[15] Researchers at Virginia Tech have recently developed a software program to help manage nonpoint source pollution that takes into account dozens of factors, including slope, soil type, and other site-specific criteria, to develop a best practice approach to managing stormwater runoff in a particular location.[16] The software program uses computer models to evaluate the efficiency of various management plans. It is currently undergoing a trial run and will soon be available free of charge to watershed management experts everywhere.

Scientists elsewhere are using IT to figure out how best to reduce and manage the runoff from urban soil that pollutes nearby streams and rivers. Researchers in Scotland, for example, have been experimenting with Web-based GIS decision management tools to better figure out what to do with contaminated urban soil. The Scottish researchers' application spatially models data about soil conditions and helps decisionmakers better understand the available management options and relative impacts.[17] Moreover, the tool offers Web-based transparency of the decisionmaking process for soil management, thereby enabling concerned local residents, nongovernmental organizations advocating for urban environmental quality, and others to gain access both to the details of decisions that affect the quality of their environment and to the details of the underlying decisionmaking process. With better information, citizens can more effectively oversee the policymakers who represent them, thereby ensuring that government is more responsive on water pollution and other environmental matters.

Pesticides, fertilizers, and herbicides are a fundamental component of the large-scale modern farming that feeds much of the world because they support increased crop yields, but with agriculture accounting for 38 percent of worldwide land use,[18] agricultural runoff (surface water containing these and other contaminants) has emerged as a primary threat to watersheds around the world. IT-enabled technology, though not a panacea, has the potential to diminish the problem of nonpoint source pollution from agricultural runoff.

An important area of IT-enabled technological innovation to reduce water pollution caused by agricultural runoff is the use of smart application processes to apply fertilizers, pesticides, and herbicides. GPS-enabled tractors with sensors, for example, can ensure that farmers apply fertilizers more efficiently and do not fertilize the same places more than once. In addition, researchers are experimenting with smart application processes that can reduce the need for herbicides. Using herbicides is an imprecise method of fighting weeds because both crops and weeds are doused in chemicals. Tractor-mounted smart sprayers outfitted with vision sensors can automatically identify weeds and deliver herbicide in tailored amounts.[19] Targeted applications of herbicide can reduce overall herbicide usage, saving farmers money and reducing the impact of such products on the soil and surrounding bodies of water.

Advanced robotic applications such as the Hortibot could dramatically reduce herbicide use by going back to the old-fashioned way of managing weeds—picking them by hand.

Another technology being developed by Danish scientists to help reduce agricultural runoff is a remote-controlled robot, called a "Hortibot." Hortibot relies on visual sensing to navigate crop rows with relative autonomy—even turning at the end of each row to proceed down the next—and will soon be outfitted with either precision herbicide-spraying or manual weed-removal tools.[20] Although the Hortibot is still costly—purchasing one will set a farmer back about $55,000—advanced robotic applications such as the Hortibot could dramatically reduce herbicide use by going back to the old fashioned way of managing weeds—picking them by hand, only in this case, by a robot's hand.

Understanding Aquatic Ecosystems

Scientists are turning to a host of IT-enabled technologies, including sensor networks and sophisticated computer models to improve their understanding of complex aquatic environments and pollution. The Beacon

Institute, IBM, and Rensselaer Polytechnic Institute scientists are participating in an innovative project that is installing sensors along the entire Hudson River in New York. These sensors, many of which will be suspended from buoys, can transmit data wirelessly to shore and will reveal for scientists a virtual river, including information about pollution levels and the state of marine life.[21] The researchers also plan to deploy a solar-powered underwater robot armed with sensors in the Hudson River to augment the data collection.

With a more comprehensive understanding of the entire ecosystem of the Hudson River, scientists will be better able to gauge the environmental impacts of pollution and be better able to detect in real time new pollution sources, making it more likely that the sources can be stopped in a timely manner. Years ago, when many of us were children, we had no qualms about jumping into a river, stream, or ocean to go swimming. As parents today, we might caution our children against jumping in some places because we simply do not know how safe the water is. In the foreseeable future, there might be IT-enabled sensor systems on all kinds of bodies of water that might be accessed just by pressing a few buttons on a cell phone. Even today groups like Earth911 offer online maps that display current beach information such as water quality and weather.[22]

Similar projects have endeavored to map other aquatic ecosystems. In Rhode Island, for example, the MapCoast and BayMap Partnerships are using sophisticated imaging technology to learn about plants and animals that live on the floor of Narragansett Bay. They are using advanced imaging tools to construct digital terrain models that are designed to understand better how bottom-dwelling organisms—a fundamental piece of the ecosystem that supports life throughout the Narragansett Bay—respond to water pollution.[23] Even more ambitiously, MIT's Darwin Project has developed a computer model that mimics 10 years of evolution of an array of underwater microscopic plants, such as phytoplankton—all governed virtually by the rules of natural selection. The project is novel because it more accurately reflects the messy complexity of life and evolution than previous efforts, and as a result its "evolution" processes has produced species of phytoplankton very similar to those that have actually evolved in the real world.

Understanding the complex processes that govern ocean microbes is important in a world in which humans are adding carbon dioxide to the atmosphere because ocean microbes help to regulate atmospheric carbon dioxide and produce half of the atmosphere's oxygen.[24] The IT tools required for such complex analysis are still relatively new, but scientists' understanding of such interactions is growing quickly as the models become more sophisticated.

Facilitating Recycling

Only a few years ago, recycling required extensive sifting and sorting to separate the different types of recyclable materials before setting them on the curb. Now thanks to a new technology called single-stream recycling that relies on automatic sorting machines underpinned by advanced IT, more and more businesses and homeowners today can recycle their bottles, cans, and newspapers by throwing them in a single bin for collection without giving the matter another thought.

MIT's Darwin Project has developed a computer model that mimics 10 years of evolution of an array of underwater microscopic plants—all governed virtually by the rules of natural selection.

Automatic sorting machines improve the efficiency and speed with which recycled material can be sorted. Such machines employ conveyor belts to carry recycled materials past devices that identify and sort them. Magnets pull metal objects out of the stream into one bin, while optical sensors identify paper and plastics, then eject them by targeted jets of air into another bin. Computers rely on the frequency of reflected infrared light that indicate the type of plastic of a particular object for separating plastics by material. The automated process operates with accuracy rates generally over 90 percent.[25]

Single-stream recycling made possible by the automated sorting machines encourages residential recycling by simplifying the process for households.

In fact, recycling rates have increased by almost 30 percent for people who live in areas where the single-stream recycling system has been implemented.[26] And the ranks of single-stream recyclers are growing both in the United States and around the world. Waste Management Recycle America already operates 27 single-stream recycling plants in the United States.[27] Titech, a leading Norwegian manufacturer of the sorting machinery, has delivered over 800 of them to Australia, Korea, Japan, countries in Europe, and the United States, with more on the way.[28]

People who are highly motivated to do the "right" thing already engage in recycling, but more people would recycle if they could receive a more direct benefit for recycling. IT already underpins the deposit refund incentives that encourage people to return bottles and cans. The machines typically found at supermarkets that accept bottles and cans in exchange for deposit refunds rely heavily on IT-driven identification systems to sort and collect deposited bottles and cans with high accuracy.

But now the city of Philadelphia is taking things a bit further. It is using radio-frequency identification (RFID) tags on recycle bins to track the amount of recycled material that households leave out for collection, rewarding consumers for their participation with coupons redeemable at local businesses. Philadelphia's system uses scales mounted on the recycling truck's forks to weigh each household's recyclables; and computer software on the truck communicates with each household trash bin's individual RFID tag, tracking the amount of recycling for each household in an online database. Consumers, in turn, can track online the money they accrue in "recycle dollars" for their efforts. Since the implementation of Philadelphia's incentive program, recycling rates have skyrocketed, reaching 90 percent.[29]

Through a handful of applications, IT makes recycling easier for consumers while boosting the efficiency of the process and utility of recycled materials.

Preserving Biodiversity: Resource Conservation and Saving Endangered Species

No less important than controlling the pollution and waste that humans produce is the task of ensuring that humans make responsible use of the finite resources that they consume. To obtain these critical resources, humans rely on the world's forests, bodies of fresh water, and mineral deposits, among others. Unfortunately, however, our demands can threaten these delicate ecosystems, depleting precious resources, and endangering the natural biodiversity of these areas.

As global population growth and economic growth place an increasing strain on the world's resources, IT has become a critical tool in efforts to conserve them. Thanks to IT, there have been dramatic improvements in data-processing, satellite-tracking, and remote-sensing technologies that permit improved monitoring and management of the world's increasingly threatened ecosystems and endangered species. IT is also making it possible for conservationists to communicate and work together more easily.

Protecting Sensitive Environmental Areas

Protecting sensitive environmental areas from damage caused by humans requires first and foremost information—and, ideally, information in near real time. The need for information is nowhere more critical than in preserving rainforests, which are home to over 50 percent of the world's plants and animals.

By definition, rainforests are a renewable resource. But old growth forests, supported by mature trees and often home to a vast array of flora and fauna, take many—even hundreds—of years to regenerate fully after being cleared. Rainforests are the most conspicuous example of such old growth forests. With their diversity of life, rainforests are a treasure in their own right, not to mention that such diversity offers the promise of new cures for life-threatening diseases. Yet by some estimates, 37 plant, animal, and insect species become extinct each day due to rainforest deforestation. Because of deforestation, rainforests now cover less than 2 percent of the Earth's surface, and tropical rainforests are particularly under threat, having declined in total area from their original 6 million square miles worldwide to the current 2.6 million.[30]

Using geographic information systems (GIS), remote-sensing, and satellite-tracking technology, governments and nongovernmental organizations

are able to monitor closely the existing rainforests remotely and, as a result, can more efficiently and effectively ensure their preservation. Scientists at Woods Hole Research Center in Falmouth, Massachusetts, for example, are working with the Japanese Space Agency (JAXA) to generate advanced satellite images of the Amazon rainforests at unprecedented clarity (25-meter resolution).[31] These frequently updated "snapshots" reveal much about the current state of the Amazon rainforests and where land has been cleared. Thus, they provide rainforest monitoring programs a critical tool for enforcing preservation agreements and fighting deforestation.[32] With more accurate and timely rainforest monitoring comes greater leverage for conservation efforts.

Rainforest advocates in the Amazon have also enlisted the help of local tribes to protect large swaths of rainforest. Members of local tribes, armed with handheld GPS units provided by the Virginia-based Amazon Conservation Team, have been mapping their lands by foot, using the technology to create electronic maps of land to cordon off from development and the accompanying pollution that it brings.[33] With Internet-accessible computers, the tribes monitor Google Earth's satellite images of their lands, identifying possible incursions for further investigation and informing governments of such activity.[34] IT is similarly supporting efforts to gain a better understanding of Central African rainforests and the logging that threatens their preservation. Woods Hole researchers have used satellite images dating from 1976 to 2003 to understand how logging has affected the forests over time. The goal is to translate this understanding into working with policymakers to develop better planning for future logging.[35]

Beyond rainforests in the Amazon and elsewhere, forest preserves in the developed world require vigilance to prevent disruptive human activities such as illegal hunting and waste dumping. Traditionally, preventing these disruptive human activities has required the stewardship of forest management staff—an expensive, and not always effective, proposition. A project in northern Maine has recently demonstrated the viability and cost-effectiveness of using aerial and satellite monitoring to monitor the 760,000-acre Pingree Easement as an alternative.[36] An IT-enabled surveillance system such as this dramatically reduces the need for forestry staff because field trips into the forest preserve (now facilitated by handheld GPS units) become necessary only when a problem is identified in high-resolution satellite and aerial photography. With its aerial and satellite surveillance system, the Pingree Easement's yearly management costs have dropped to below $70,000—an amount much less than the estimated cost of several hundred thousand dollars for traditional management practices.[37]

Uniting Conservationists

Movements to preserve threatened natural areas enjoy popular support among legions of environmentally conscious citizens and outdoor enthusiasts, and IT plays an important role in these movements in a way that has nothing at all to do with actual resource management—by uniting people who support conservation. As noted elsewhere in this report, the Internet facilitates communication between people with shared interests. People in conservation movement fall into this category. Thus, for example, groups like the Nature Conservancy rely heavily on the Internet to reach their base of members and donors, informing them of important conservation developments and soliciting contributions.

Many conservation problems, like rainforests, are geographically distant from the majority of the people who care about them. Internet-delivered images, video, and interactive applications can vividly communicate information about such problems to people who are far away. A Web video showing a seal covered in oil in the wake of a spill, for example, or a blog about a situation can be far more compelling and effective than a traditional media report. In addition, IT-enabled technology can be used to tailor conservation groups' messages to make them relevant to particular individuals. As an example, ilovemountains.org, an organization committed to eliminating the practice of mountaintop strip mining in Appalachia, prompts site visitors to enter their zipcode to determine whether their electricity relies on Appalachian coal removed taken from mountaintop mines (if you live in the United States, it probably does). Through the website's Google Maps interface, visitors can learn about their connection to the practice, find out more about the mountaintop mines that supply their electric utility, and learn

how to take action to end the mining. This is but one example of how the Internet is facilitating and promoting individual and collective action in the environmental movement.

Saving Threatened Species

Scientists and governments are turning to advanced IT tools to learn about and preserve the habitats of threatened species, as well as to combat animal trafficking and poaching, which, despite their general prohibition, threaten the extinction of many species around the world.

With human-driven development continuously encroaching on remaining wildlife habitats, the threats to animal populations are often myriad and growing. Wildlife experts have only recently been able to apply advanced IT tools for tracking animals in order to understand more precisely the habitat needs of mammals, birds, and various other threatened species. In the case of one critically endangered species, spotted owls, the birds have been fitted with tiny radio transmitters that allow researchers to track their movements by triangulating the signals. By combining this information with GPS readings, researchers are able to track spotted owl locations in real time. From compiling these data over time, researchers then construct maps of each unique owl's home range.[38] As a result, they know the habitat that needs protection from human incursion.

Similarly, the World Wildlife Fund has begun tracking peccaries (tusked pig-like animals) in the Amazon using RFID tags clipped to the animals' ears.[39] The organization is using the findings to inform its advocacy for wildlife habitat needs in the Amazon region. Monitoring endangered species, especially at birth, can be key to their survival in the wild, yet monitoring can also be cumbersome and risky to the wildlife. To solve the problem, the U.S. National Aviary uses webcams to monitor peregrine falcon nests; feeds are then uploaded onto its website, where experts can remotely observer the birds.[40]

Some researchers have used IT to help track the migration of birds. Monitoring bird flight is crucial in order to preserve the wildlife habitats vital for bird migration. Before IT-enabled tracking devices were developed, processes to track bird migration were costly and inaccurate.[41] Currently, one bird migration project uses thousands of tracking devices on North American rooftops connected to home computers to capture bird sounds, which scientists can then use to identify bird species, numbers, and flight characteristics. Another project currently under development is planning to attach tiny wireless devices to small birds called prothonotary warblers to track their migratory patterns using cell phone towers. A better understanding of prothonotary warblers' migration patterns, say the researchers at Oregon State University responsible for the project, will yield insights into the birds' population declines.[42]

Tracking of a different sort is underway in northern Canada, where researchers are attempting to gauge the decline of the northern polar bear population. Wildtrack, an organization devoted to tracking polar bear population levels, has developed a database for tracking polar bears by digital photographs of their footprints, relying on computer algorithms that match anatomical characteristics unique to each animal.[43] From their observations and matching analysis, researchers can learn about the size of a polar bear population in a particular area and each animal's unique movements.

Anti-animal-trafficking activists in Zimbabwe use the same technology to collect and aggregate digital photographs of black rhino footprints and use GPS to plot the location of each snapshot. Knowing that the animals' footprints last only about 24 hours, they are able to create a precise map of each black rhino's movements.[44]

Animal trafficking involves the illegal trade of rare animals for private collectors, biopiracy, pet animals, and poached body parts. The trade is widespread in places like Brazil, where an estimated 38 million animals are poached every year, and over 600 species are now threatened by extinction.[45] Though the illicit trade has long operated in the shadows, that is now changing thanks to the Internet. One Brazilian group, RENCTAS, has used the Internet to raise public awareness, much the way other nongovernmental organizations have worked in other areas, but the group has now taken its Internet operation a step further. Rather than simply reaching out to the constituency of mobilized supporters, RENCTAS actively engages in the fight against animal traffickers, soliciting anonymous tips to protect informants, and scouring websites, posing as potential buyers. The group turns over its information to the authori-

ties to act on it.[46] Because animal traffickers are often organized and dangerous, the Internet's anonymity is crucial in the organization's efforts to fight them.

Poaching is another problem that threatens animal species. Despite laws protecting species like elephants and tigers, the black market ensures the continued poaching of these animals for their ivory tusks and pelts. Like the destruction of the natural environment, animal poaching is in part an information failure. Animal poachers can get in and out, doing their damage, before officials know what happened. Now IT-enabled tools are helping authorities catch up with the criminals. Scientists at the University of Washington, for example, have geographically mapped the genetic variations of African elephant population.[47] By analyzing genetic evidence gleaned from seized tusk shipments, the scientists are able to track the origin of the elephants—a major step in international investigations of the banned elephant ivory trade. The University of Washington researchers and several African governments hope to expand the genetic tracing, which relies on IT-enabled analysis, to other threatened species, including tigers. But genetic analysis is not only useful for combating poachers. A better understanding of the locations where closely related populations of a certain species live gives scientists a window into natural migratory patterns, and how best to restore them.

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