

An outbreak of eco-immunology research

Virginia Gewin

In 1991, ecologist Paul Schmid-Hempel, currently at the Institute of Integrative Biology in Zurich, Switzerland, found a correlation between parasite load and reproductive timing in bumblebee (*Bombus* spp) populations, but there was no plausible process to explain the relationship. Thirteen years later, Schmid-Hempel determined that bumblebee populations challenged with a pseudo-infection are both less fit and reproduce earlier in the year than normal. “We finally had a link between a mechanism of immune defense and the timing of life history in the field, one that tallied a price paid for parasitism”, he says.

Schmid-Hempel’s research was among the first studies to bridge ecology and immunology. Since 2004, a rash of research papers has firmly established a field called “eco-immunology”. The goal: to better understand the costs of, and variations in, the immune defenses of wild animals.

“Ecologists can no longer ignore immunology”, acknowledges Amy Pedersen, an ecologist at the Center for Immunity, Infection and Evolution (CIIE; Edinburgh, UK). Writing in the March 2011 issue of *Molecular Ecology* (doi:10.1111/j.1365-294X.2010.04938.x), Pedersen described eco-immunology as the missing link between laboratory-based immunology and human, wildlife, and domesticated animal health. In addition, the February issue of *Functional Ecology* was entirely devoted to the generalities identified so far in immune systems among vertebrates, invertebrates, and even plants (doi:10.1111/j.1365-2435.2010.01820.x).

This rapid progress is due in no small part to the budding partnerships between ecologists and immunologists. Lynn Martin, a physiological ecologist



Field crews take measurements of Soay sheep in Scotland.

at the University of South Florida (Tampa, FL), explains that ecologists have struggled to adequately measure immune function. “It was hard to know what to measure, and then to know what it meant”, he admits.

The disparate jargon and conceptual frameworks were formidable hurdles to overcome. For example, immunology experiments are conducted under extremely controlled conditions; reducing variation among individuals is essential for deciphering mechanisms at work. Yet, for ecologists, it is the variation in natural populations that helps explain population dynamics. Luckily, a few immunologists are eager to step into the field. Pedersen’s colleague at CIIE, Simon Babayan, is an immunologist developing vaccines against parasitic worms. “We are typically able to kill roughly 70% of parasites [in infected animals], but that percentage is highly variable, even under controlled lab conditions – which is my worry”, he adds. Babayan hopes that collaborating with ecologists will help him understand existing variation in order to design vaccines to protect wild populations.

The lack of tools has been one of the biggest limitations to the field. For example, reagents necessary for conducting immunological assays on wild organisms don’t currently exist, and developing such assays is quite expensive. While much of the eco-

immunology research to date has focused on birds or insects, a growing number of studies are looking at species related to domestic animals, including livestock and lab mice, for which existing reagents can be more easily adapted.

This past fall, Andrea Graham, an ecologist at Princeton University (Princeton, NJ), achieved one of the field’s landmark steps. Combining 11 years of demographic data with blood antibody concentrations in Scottish Soay sheep (*Ovis aries*), she and colleagues showed that female sheep with strong immune systems live longer – but at the cost of reduced reproductive rates (doi:10.1126/science.1194878). Sheep with lower concentrations of antibodies were shorter-lived but reproduced more often. While Graham was thrilled to discover this relationship, she believes that much variation among the sheep remains to be accounted for, in part due to the complexities of immune function.

Graham’s achievement makes clear the importance of studying wild populations in which the individuals can be repeatedly caught and sampled. For this reason, Anna Jolles, a disease ecologist at Oregon State University (Corvallis, OR), studies African buffalo (*Syncerus caffer*) in South Africa’s Kruger National Park, in the hope of better understanding how immunity plays out at a population level. Twice a year, Jolles and her team collect blood samples from 200 buffalo, to monitor roughly 18 different pathogens or parasites. And that’s just the pathogens known to be a problem. “In most wildlife systems, we simply don’t know how many pathogens are present”, she says.

As these studies demonstrate, the complexity of immunological research in natural systems is daunting, and is only getting more so as researchers uncover how other variable factors, such as nutrition or stress, affect immune-system function. But Graham hopes that eco-immunologists’ efforts will begin to partition the major causes and impacts of variation – and perhaps even to discover generalities that apply across taxa. ■

Mun River dam demands Mekong rethink

Adrian Burton

Protests by local residents demanding that the gates of a failing hydroelectric dam on Thailand's Mun River be opened permanently – in order to repair ecosystem damage and restore livelihoods – are highlighting fears surrounding other dam-building projects in the Mekong Basin.

The history of the 17-m-high, 300-m-wide, US\$260 million Pak Mun Dam, built in 1994 near the confluence of the Mun and Mekong rivers, has been one of failure. The World Commission on Dams case report indicates it can generate only 15% of the electricity originally intended – at the cost of 1700 displaced households, a huge decline in the river's fish stocks, the loss of many fish species, and destabilized food security. "If plans and policies were adequately implemented with respect to social impacts and resolution of conflicts, villagers would not have had to waste time and effort in negotiating and protesting against the dam. Nor would the country as a whole have lost an important



The Pak Mun Dam on Thailand's Mun River.

ecosystem", the document concludes (www.dams.org/kbase/studies/th/th_exec.htm).

Since January, protestors have been insisting that the Thai Government approve the permanent opening of the dam's gates, following a December 2010 promise by the Prime Minister's Office Minister Sathit Wongnongtoey to seek such an undertaking. At the time of writing, none had yet been guaranteed.

Meanwhile, plans for the larger Xayaburi Dam on the main course of the Mekong in northern Laos, plus those for 10 other dams in Thailand, Laos, Cambodia, and Vietnam, progress. Fears that the Pak Mun lesson has gone unlearned are founded in the latter nations' 2010 consultation and agreement process on the Xayaburi

New system removes arsenic from groundwater

Noreen Parks

New technology that substantially reduces concentrations of toxic, waterborne arsenic and delivers low-cost, potable water is poised to spread around the world. Known as subterranean arsenic removal (SAR), the pioneering method doesn't use chemicals or generate waste products.

Natural sources of arsenic pollute aquifers worldwide, affecting an estimated 137 million people, particularly in areas where groundwater provides drinking water supplies. Soil bacteria obtain oxygen by dissolving mineral-bound arsenic, which then enters groundwater, a process that is accelerated by the huge quantities of fertilizers used in agriculture, explains environmental engineer Bhaskar Sen Gupta (Queen's University, Belfast,

Northern Ireland). Conventional treatments pump groundwater to the surface and pass it through chemically treated filters to trap arsenic and heavy metals, but such plants are expensive, generate waste sludge, and require skilled maintenance. Sen Gupta and colleagues from India and Europe developed a simpler, more affordable technology, largely comprising basic plumbing components.

The SAR system aerates pumped groundwater and sends it back into the aquifer to supply oxygen for the bacteria, allowing them to shift from producing toxic aqueous arsenic to making benign precipitates of arsenic (and iron) that remain trapped belowground. "SAR effectively turns the aquifer into a natural biochemical reactor, to reverse the mechanism that creates the problem", Sen Gupta continues.

With financial help from the World

Dam, which started 3 weeks before the release of the strategic environmental assessment (SEA) commissioned by the Mekong River Commission, the body mandated by the four countries' governments to manage the Mekong. The SEA in fact recommended that building be deferred for 10 years, since present knowledge was insufficient to estimate the dam's impact.

"Currently, we can't predict the effects of any mainstream dam", says Suphasuk Pradubsuk, National Policy Coordinator with WWF-Thailand (Bangkok). "And the feasibility study of the Xayaburi Dam by the CH Karnchang Public Co Ltd [the dam's future builders and operators] blandly assures us that the impacts will be low level, without providing anything much to justify this."

Unfortunately, no reply was received to questions faxed to CH Karnchang in Bangkok. However, its website carries the general environmental statement: "The Company realizes such impacts during the construction on environment and community, therefore a framework has been set to efficiently prevent such impacts" (www.ch-karnchang.co.th/about_environmental_en.php). ■

Bank, six SAR systems have been successfully installed in West Bengal, India, since 2006, and plans are underway for additional SAR plants in Cambodia, Vietnam, and Mexico. SAR is also making its debut in the US, in a rural area of northwestern Washington State, where arsenic in well water can reach 300 parts per billion (ppb; the US EPA standard is 10 ppb). Sen Gupta recently assisted local residents in setting up an experimental trial, with encouraging preliminary results.

Development costs for a SAR plant that produces about 1600 gallons of water a day average under US\$4000 – less in the developing world – and the monthly operational cost is around US\$20. The technology has won several international awards, but the biggest payoff, Sen Gupta says, is the improved quality of life in rural communities. ■

Floods a mixed blessing

Claire Miller

Australia's worst drought on record has ended with the wettest summer (December–February in Australia) on record, leading to widespread flooding that reinvigorated some ecosystems but damaged others stressed by the 15-year-long “big dry”.

The “big wet”, which set in last September as an intense La Niña, developed in conjunction with the first negative Indian Ocean Dipole (a phenomenon involving irregular climatic oscillations) since 1996, has caused nearly 40 deaths since November. While insurers are still assessing the property damage, scientists are monitoring environmental impacts, which range from frenzied native fish breeding to silt plumes choking inshore reefs.

In Victoria's Goulburn River, endangered native golden perch (*Macquaria ambigua*) have been observed breeding en masse after floods allowed them to move out

onto normally dry floodplains, where they gorged on previously inaccessible food. “We've monitored golden perch here for 8 years, and this was the first time we detected a spawning event of any size”, says fish ecologist Wayne Koster (Arthur Rylah Institute, Melbourne, Australia). However, a major “blackwater” event, caused by drought-accumulated organic material washing into the nearby Murray River, stripped its waters of dissolved oxygen and resulted in large fish and crustacean kills downstream. Although blackwater events are a natural phenomenon, Andrew Beal of the South Australian Water Department (Adelaide) acknowledges that this was a “big one”.

Environmentalists argue that the severity of the Murray blackwater event underscores the need to reduce irrigation diversions. “Had environmental flows been available to recreate even a minor flood during the past drought, the most extreme effects of the blackwater event would

have been reduced”, says John Pettigrew (Environmental Farmers Network, Bunbartha, Australia).

Meanwhile, authorities in Queensland are looking at how muddy flood plumes – covering an expanse equivalent to more than 10% of the Great Barrier Reef – affect both seagrass beds and coral reefs. Andrew Skeat (Great Barrier Reef Marine Park Authority, Townsville, Australia) points out that the flood runoff could increase rates of algal blooms, coral bleaching, and coral disease, but may also enhance the productivity of some inshore species, such as barramundi (*Lates calcarifer*), mangrove jack (*Lutjanus argentimaculatus*), and some species of prawns. “Even when [organisms] are exposed to freshwater plumes, they do not necessarily die. Many plants and animals have short-term mechanisms to cope with low salinity and low light”, he explains. “However, this event involves unusually large amounts of runoff with suspended material, and the prevailing conditions may be different from previous events.” ■

Plight of the living dead

Chelsea L Wood

Shakespeare's Hamlet would have us believe that there are more things in heaven and earth than are dreamt of in our philosophy. A report in the March 2011 issue of *PLoS One* (doi:10.1371/journal.pone.0017024), documenting four newly described species of “mind control” fungi from the Atlantic rainforest of Brazil, suggests that the Prince of Denmark was right. The findings suggest that other improbable species interactions remain to be discovered in the world's biodiversity hotspots.

The new fungal species are parasites that infect Brazilian carpenter ants (*Camponotus* spp) and are able to manipulate host behavior to facilitate their own reproductive success. Harry Evans (Federal University of Viçosa, Minas Gerais, Brazil), an author of the paper, explains: “The fungal spore attaches to the ant's cuticle...and



An internal parasitic fungus erupts through an infected ant's cuticle.

punches its way through the exoskeleton using both physical and enzyme pressures. At some stage, neurotoxins are released that alter ant behavior.” Through this fine-tuned neurological control of its host, the fungus is able to direct the ant to leave its colony, search out a location that matches the temperature and humidity preferences of the parasite, and lock its mandibles onto the edge of a leaf. The fungus then kills its ant host and produces a stalk, which emerges from the cadaver to shower spores upon other ants on the forest floor below.

These parasitic fungi had been previously known to science, but were recognized as only one species. David Hughes (Pennsylvania State University, University Park, PA), a coauthor of the paper, suspects that there are many additional cryptic species awaiting discovery: “We think there will be hundreds. There are definitely other species where we work in Brazil, and that is a tiny patch of forest. What happens if one travels across the 2000-mile stretch of the Amazon? And then across Africa and Asia?”

Hughes continues: “In the end, having a few additional species doesn't change much”. But he and Evans explain that – given the ecological importance of ants and the severe pathology and high prevalence of their parasites – such fungal parasitism could be an important influence on tropical forest ecosystems. At the very least, the work suggests that there are many more bizarre discoveries to be made in the world's biodiverse regions. ■

Bubble barrier to steer salmon clear of pumps

Robin Meadows

California officials are testing a new way to keep young salmon out of the massive pumps that divert water from the state's wet north to its thirsty south, which contains 60% of California's human population and supports much of its agriculture. The pumps suck up and kill threatened Chinook salmon (*Oncorhynchus tshawytscha*) during the spring run, when juveniles migrate downriver through the Sacramento–San Joaquin Delta toward the Pacific Ocean. This salmon run now averages just 2500 individuals per year, down from an estimated historical high of 700 000.

Young salmon reach the pumps via the Georgiana Slough, and nearly two-thirds of those that swim into the Slough die. To help keep them out, the state Department of Water Resources (Sacramento, CA) has recently installed a temporary “bubble barrier” across the head of the Slough.



California Department of Water Resources

Would you swim through this? California officials hope young salmon won't.

Composed of a combination of tiny bubbles, flashing lights, and low-frequency sounds (up to 170 decibels, which is louder than a jet engine at takeoff), this non-traditional barrier will be in place until late spring.

While likely to deter young salmon from the Slough, fish expert Peter Moyle (University of California, Davis) cautions that “the bubble barrier is a band-aid solution”. For one

thing, whether this will actually increase the number of returning adult salmon remains unknown. For another, the barrier fails to address a major problem caused by the pumps: by drawing water across the Delta, they disrupt the natural water flows to which salmon have adapted. As noted in *Managing California's Water: From Conflict to Reconciliation*, a report published earlier this year by the Public Policy Institute of California (San Francisco, CA), “The Delta functions less like an estuary with strong upstream–downstream gradients, and more like a confused lake”.

In addition to re-establishing natural flow patterns in the Delta, long-term fixes for the salmon would include restoring flood plains and increasing water flows below the many dams that block rivers feeding into the Delta. “If we Californians want to have wild salmon around in the future, we will have to be willing to change the way we manage our water system, so that it provides more ecosystem benefits”, concludes Moyle. ■

Grazing can help reduce greenhouse gases

Johanna Polsenberg

Over a 12-year period, scientists working in the US Department of Agriculture (USDA) Agricultural Research Service's Climate Change, Soils, and Emissions National Program (www.ars.usda.gov/is/pr/2011/110303.htm) showed that cattle grazing may improve soil quality and enhance soil sequestration of carbon (C) and nitrogen (N). The study – led by Alan Franzluebbers, an ecologist with the USDA (Watkinsville, GA) – assessed how soils in the southeastern US responded to four different grazing scenarios: moderate grazing; intensive grazing; no grazing and allowing the grass to grow; and no grazing but removal of the grass by mowing. They also varied fertilizer treatments and found that grazing led to the most C and N being sequestered in soil, while fertilizer alone made little difference (*Soil Sci Soc Am J* 2010; doi:10.2136/

sssaj2010.0034). Soil compaction was similar among the moderate grazing and both of the no-grazing scenarios but was slightly higher under intensive grazing. “From an environmental standpoint, grazing has traditionally been viewed as less desirable than leaving the land unused”, explains Franzluebbers. “However, these results demonstrate that if producers allow cattle to moderately graze pastures, they'll be restoring soil quality and cutting greenhouse gases (GHGs) by keeping C in the soil as organic matter rather than releasing it into the atmosphere as CO₂.”

“If done properly, grazing might be able to improve soil quality”, agrees Kim McCreery, a Regional Director with the New Mexico Wilderness Alliance (Silver City, NM). But McCreery cautions against extrapolating results from a warm–humid region to the arid Southwest, where land-use debates over grazing are more intense. According to Caren Cowan, Executive Director of the New Mexico

Cattle Growers Association (Albuquerque, NM), “Stocking rates in the West are vastly different from those in the Southeast. The general rule in the Southwest is to run one animal on every [24–49 hectares] of land, depending on the terrain and current climate conditions.” Stock densities in Franzluebbers' study were considerably higher, at 5.8 and 8.7 animals per hectare for moderate and intensive grazing, respectively. Franzluebbers added that a decline in soil organic matter was observed during periods of drought.

Wilma Jenkins, owner of the Double Circle Ranch (Clifton, AZ), has been testing different methods for sustainable ranching in the arid West. “I believe well-managed grazing could do more than anything else to reduce GHGs, raise water levels, provide wildlife habitat, and protect riparian areas”, says Jenkins. “Plus, it produces food and uses no heavy equipment or fuel. It is a total win–win deal.” ■

No more “Green the Capitol”

Jen Fela

Tensions are high on Capitol Hill, in Washington, DC, where recent moves by the Republican transition team to save money have brought Styrofoam cups and plastic utensils back to Congressional cafeterias and ended the composting program, leaving many Democrats and environmentalists seeing red instead of green.

Nancy Pelosi (D-CA) initiated the “Green the Capitol” program when she became Speaker of the House in 2007. This program aimed “to make the US House of Representatives a national leader in resource stewardship and sustainable business practices”, according to its website (<http://cao.house.gov/greenthecapitol/>). In addition to using biodegradable utensils in cafeterias and composting food left-

overs, the initiative included recycling office paper, installing low-flow toilets and energy-efficient lighting, and converting the Capitol power plant from coal to natural gas.

But the Committee on House Administration recently withdrew funding from the program, claiming that the composting portion “costs an estimated \$475 000 annually, has actually increased the House’s overall energy consumption, and produced nominal reductions in carbon emissions”. Dan Lungren (R-CA), Chairman of the Committee, claims, in a written statement, that the program is “neither cost effective nor energy efficient”, but that the Committee would “continue to evaluate all components of House operations and work with appropriate agencies to incorporate environmentally sustainable practices when feasible”.

Earl Blumenauer (D-OR) is lead-

ing an effort to reverse the decision. According to his website (<http://blumenauer.house.gov/>), “To date, the [composting] program has resulted in the diversion of 10 000 tons of waste from landfills, the reduction of 28 000 metric tons of CO₂, and the conservation of 16 million kilowatt-hours of electricity. The program has saved taxpayers over \$3 million and has the potential to save more than \$5 million annually”.

“As the seat of our Federal Government, the Capitol has to set an example for the rest of the country”, says Nick Berning, spokesperson for Friends of the Earth. “The new House majority’s move to end waste-reduction efforts in the Capitol cafeterias is shortsighted. The hundreds of tons of non-biodegradable waste created by this action will spend the next thousand years in a landfill, causing problems for generations to come.” ■

Cane toads: a new approach to control?

Jane Bradbury

New research suggests that exclusion of cane toads (*Bufo marinus*) from artificial water points (AWPs), which act as invasion hubs, might contain their spread in arid regions of Australia. “Fencing off AWP is not a silver bullet”, warns researcher Mike Letnic (University of Western Sydney, Penrith, Australia), “but could be effective as part of an integrated approach to cane toad control”.

Since their intentional introduction into Queensland in 1935 to control beetles that destroy sugar cane, these amphibians, which are poisonous throughout their life cycle, have spread and devastated populations of several native predators.

Letnic and his colleagues became interested in cane toad control while working in the Victoria River catchment area in the Northern Territory. Here, during the late dry season (September to November), average maximum daily temperatures are around 40°C (104°F) and the only sources of natural water are discon-



Cane toad with tracking device.

nected pools. However, farmers have established AWP at regular intervals for their cattle. “We were cooling off one day by swimming in one of these [reservoirs]”, explains Letnic, “and we found a huge number of toads in the water”. We didn’t see any cane toads elsewhere in the immediate area, he says, “so we thought, if we could keep them out of AWP, maybe we could eradicate them locally”.

The researchers tested their idea by excluding cane toads from AWP during the late dry season with small fences. Radio-tracked toads released outside fenced AWP died within 72 hours, whereas radio-tracked toads released outside unfenced AWP sur-

vived. Toad abundance at fenced AWP also reduced rapidly after fence installation but varied little at unfenced AWP. Finally, the researchers used data on the distribution of permanent water sources and the dispersal potential of toads to predict that systematic exclusion of toads from AWP would reduce their likely area of dispersal across Australia by 38% (*P Roy Soc B-Biol Sci* 2011; doi:10.1098/rspb.2011.0032).

“This certainly suggests that water bodies serve as invasion hubs for cane toads and are likely to be important for their spread in more arid regions”, comments ecologist Ross Alford (James Cook University, Queensland, Australia). However, says Alford, the researchers’ projections for the effects of exclusion from AWP may be optimistic because cane toads also obtain water from natural watercourses, the fencing of which would be impracticable. Letnic agrees but argues that the results of his team’s research should help in identifying areas where fencing AWP might reduce cane toad populations, particularly in regions where natural sources of water are scarce. ■

Dr Dolittle meets CSI

Madeline McCurry-Schmidt

When University of Hawaii marine conservation biologist Robert Richmond (Honolulu, HI) looks at damaged coral, he sees a dying patient. The patient's immune system is under stress, and it's up to reef managers to diagnose the problem. Is the coral reacting to an oil spill or changing water temperatures? That's where the "coral whisperers" come in.

Launched in 2006 by Conservation International, Coral Whisperer is a multi-university initiative that aims to identify biomarkers in distressed coral. Richmond believes current methods of diagnostics err in relying on coral mortality to indicate reef stress, pointing out that, "If someone had to die to indicate a problem, medicine wouldn't be very proactive or responsible".

So far, the project seems to be working. For example, researchers have discovered that when coral is damaged by even small amounts of oil, certain genes are switched on, leading to the production of protective



Graduate student Nikki Traylor-Knowles (Boston University, MA), at work on a Coral Whisperer experiment for her doctoral thesis.

enzymes. Richmond explains that the use of forensic indicators such as these earned Coral Whisperer the tag-name "Dr Dolittle meets CSI".

Ultimately, the scientists want to progress from studying basic coral immunology to developing easy-to-use testing kits for reef managers. According to Boston University pro-

fessor and project leader Les Kaufman (Boston, MA), such kits could be ready in 3–5 years. At present, researchers are putting corals through what team member Steve Palumbi (Stanford University, Stanford, CA) calls "global climate-change treadmills" by identifying genes switched on by corals and their symbiotic algae in response to specific stressors like heat or abrasion. A favorite subject is *Pocillopora damicornis*, the common lace coral. "What better than to study its immune system and use it as a sentinel?", says Kaufman.

Richmond envisions a day when managers could send coral samples to his team for analysis, comparing the procedure to a physician sending blood samples to a lab for testing. "A lot of what we do is based on human medicine", he explains.

According to Kaufman, Coral Whisperer highlights the detrimental impact that climate change and pollution has on reef systems: "We use corals to diagnose the relationship between people and ocean ecosystems – that's what actually gets sick". ■

Sustainability is in the bag

Janet Pelley

Paper or plastic? If you want to save the planet, the answer to this grocery checkout question depends on how many times you plan to reuse the bag, according to a new report from the UK's Environment Agency.

Researchers with the Agency conducted a life-cycle analysis in which they compared the environmental impacts of providing, using, and disposing of the most common types of grocery bags. Bags such as those made from high-density polyethylene (HDPE) plastic, paper, and cloth were evaluated for their impacts on global warming, resource depletion, environmental toxicity, and smog formation. The analysis took into account the fact that people reuse 40% of conventional HDPE plastic bags to line their garbage pails. The researchers

then calculated how many times each type of bag would have to be used to reduce its global warming potential to below that for HDPE bags. Cloth bags would have to be reused 173 times to equal the environmental impact of plastic bags, whereas paper bags would have to be reused only 4 times to match the modest impact of plastic bags.

The UK study reveals that most of the environmental impacts come "up front", during the process of extracting resources to make the shopping bags, says Madalyn Cioci, a waste prevention specialist at the Minnesota Pollution Control Agency (St Paul). This, she adds, highlights the importance of reuse in order to minimize resource extraction.

It's not surprising that on a "use once and toss" basis, plastic bags come out on top, says Rod Muir, a waste diversion campaigner for Sierra Club Canada. Plastic bags

require less material for their production than do cotton bags, and are made from waste hydrocarbons that were formerly simply flared off at refineries. If a plastic bag is interred in a landfill, where it takes years to degrade, it could be seen as preventing the release of CO₂ to the atmosphere, Muir points out.

Canadians take home 55 million plastic shopping bags per week, according to Environment Canada. Tossed by litterbugs, these petroleum-based products clog gutters, flutter from tree branches, and harm wildlife that ingest them. Governments across the globe, from Ireland to China and Tanzania, are waging war on the plastic bag, imposing bans and fees, but, concludes Muir, "There are bigger waste problems [than plastic bags], such as batteries, anything with mercury in it, PVC plastic in packaging, and waste paint." ■