ILLINOIS NATURAL HISTORY SURVEY

Reports

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INSIDE

INHS Establishes Site for Organic Research

The Illinois Natural History Survey prairie and pond in Champaign will soon have a new neighbor—a Survey field site dedicated to organic research and education. More Americans are choosing organically produced foods at their grocery stores and farmer's markets. Organic farming has become one of the fastest growing segments of U.S. agriculture. Since 1996, U.S. sales of organic products have grown at an annual rate exceeding 20%, topping $9 billion in 2001. This growth is projected to continue, reaching approximately $20 billion by 2005.

The National Organic Standards Board (1995) defines *organic* as "an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony." Organic production systems seek to support beneficial organisms, nutrient cycling, soil tilth, and nitrogen fixation through greater crop diversity and enhanced soil biological activity. These systems rely on practices such as cultural and biological pest management, exclude the use of synthetic chemicals and genetically modified organisms in crops, and prohibit the use of antibiotics and hormones in livestock. Through the Organic Foods Production Act (1990), the U.S. Congress established national standards for organic commodities. Implementation of the organic labeling provisions took effect in October 2002.

Very little research has been done on organic systems, and organic producers have criticized federal and state departments of agriculture as well as land-grant universities for failing to provide programs to meet their needs. In a comprehensive survey of U.S. organic producers, respondents identified 1) weed management, 2) relationships between fertility management and crop health, pest and disease resistance, 3) relationships between organic management and nutritional value, 4) soil biology, 5) crop rotations, and 6) cover cropping as their top research priorities. They also expressed strong interest in whole farm planning/design, ecosystem integration, and permaculture.

To address these priorities, Survey scientists have joined

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Organic farming has become one of the fastest growing segments of U.S. agriculture. Here are a few of the many organic products found at local supermarkets. Photo by John Shaw, INHS Center for Economic Entomology

Cave Amphipod Respiration in Southwestern Illinois

The cave environment presents unique challenges to the organisms that live there. The constant and total darkness away from the cave entrance makes eyes and body coloration superfluous and many cave dwellers have no, or greatly reduced, eyes and are pale in coloration. To find each other and food, they have evolved other sensory or chemosensory structures, such as long antennae in crickets and amphipods and well-developed lateral lines in fish. The lack of light also greatly reduces the amount of food available in caves compared to surface environments. To overcome this obstacle, cave organisms generally have a lower metabolism than their surface kin. Thus, the little food that is available, often washed in from the surface, can fuel metabolic needs for a long period of time and excludes surface species that have higher metabolic demands. Other characteristics, such as longer life span, lower reproductive rate, older age at maturity and first reproduction are also associated with a low metabolism and are common among cave-adapted organisms. These characteristics make cave communities and species susceptible to invasion and extirpation by surface organisms in the face of above-normal nutrient availability, such as those associated with inadequate septic systems and agricultural practices.

The karst landscape of the Salem Plateau of Monroe and St. Clair counties contains numerous caves with streams, some of which are home to the federally endangered Illinois cave amphipod, *Gammarus acherondytes*, a true cave-adapted species, or trogolobite. Because of the nature of the karst geology, surface runoff is directed into the caves almost directly through sinkholes with little prior filtration or breakdown of wastes or chemicals. The high rate of urbanization and agricultural activity on the surface has led to higher than normal nutrient and bacterial concentrations in cave streams (*INHS Reports* 361:2). As a result, *Gammarus troglophilus*, an amphipod species associated with surface springs but also capable of living in cave streams, may be outcompeting and displacing *G. acherondytes* in the caves.

We are conducting a series of respiration experiments to determine if metabolic rates differ between the two amphipod species. We are interested in respiration rates for several reasons. First, the results will help us to better understand the respiratory requirements of the amphipods. Results may indicate a minimum dissolved oxygen concentration in the water for survival, similar to the requirements known for many fish species. Second, results will indicate whether or not a difference in metabolic rates exists, perhaps favoring *G. troglophilus* with a competitive advantage at above-normal food conditions.

Frank Wilhelm (front) of Southern Illinois University and JoAnn Jacoby of INHS search Illinois Caverns for amphipods. Photo by Steven Taylor, INHS Center for Biodiversity

To measure the oxygen consumption of amphipods, we assembled small-scale respirometers with micro-tipped oxygen electrodes that are attached to individuals. Such small electrodes consume very little oxygen themselves and are sensitive to small changes in ambient concentrations, making them ideal for our purposes. In the summer of 2002, we collected *G. acherondytes* and *G. troglophilus* from Illinois Caverns. To measure the oxygen consumption, individuals were placed in respiration chambers filled with filtered cave water and four small aquarium rocks. The chambers were then sealed, the oxygen probe inserted, and oxygen consumption measured for four hours.

More than 50 respiration runs have been completed, approximately half with each amphipod species. As expected, large amphipods consumed more oxygen than small individuals (µg O_2•animal^{-1} vs body mass). However, expressed on a per unit weight basis (µg O_2•mg tissue^{-1} vs body weight), small individuals had a higher metabolic rate, an expected relation based on the higher surface to volume ratio of small compared to large individuals. Even though large *G. troglophilus* consumed slightly more oxygen than *G. acherondytes*, a comparison between the two species has not revealed any statistical difference in metabolic rates. These respiratory rates may have been influenced by atypically low concentrations of bacteria in the groundwater, caused by the drought conditions in the summer of 2002. We are continuing the respiration experiments in February and May to account for possible seasonal influences.

In addition to learning about respiration in these amphipods, our work allows us to examine other questions. For example, very little is known about the life histories of these organisms, and by measuring the animals prior to release, we are able to collect size class data. In the laboratory we are also obtaining information about food consumption rates and survivorship.

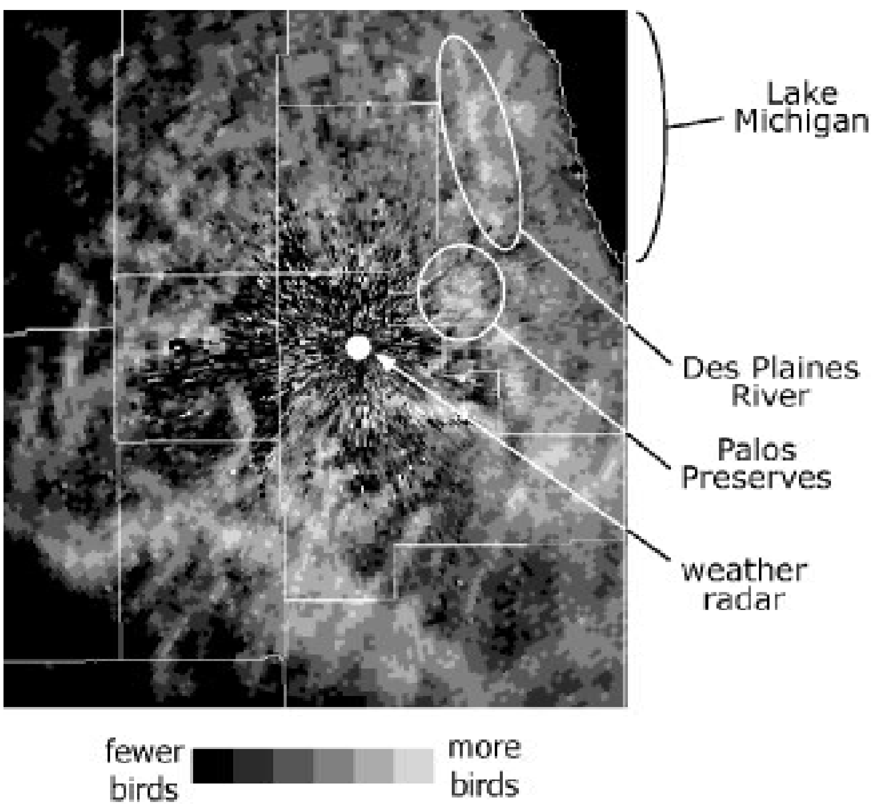
Some populations of the Illinois cave amphipod have apparently disappeared completely, or have exhibited abrupt, catastrophic declines. If we can identify factors important to maintaining healthy populations of the cave amphipods, it may be possible to affect changes (e.g., land-use practices) that help the species, the groundwater community, and water quality in general.

Michael P. Venarsky and Frank M. Wilhelm, Southern Illinois University; Steven J. Taylor, Center for Biodiversity

Weather Radars Reveal Bird Migration Patterns

A songbird arrives over central Illinois after a long nocturnal spring migratory flight. As morning twilight appears on the eastern horizon, the bird seeks the familiarity of forested habitat in which to rest and refuel before continuing north. But below, a sea of agriculture stretches to the horizon, dotted only by an occasional wooded patch. Exhausted after a long flight, the bird makes for a nearby patch. Or does it?

Although in reality we can only speculate about what goes on in a birds' head during migration, one wonders how migrating birds respond when finding themselves in inhospitable landscapes and how these responses shape their distribution in the landscape between migratory flights.



Radar captured this snapshot of the onset of migration throughout northeastern Illinois. Birds departing wooded habitats are revealed as distinct regions of strong echo.

These are tough questions to answer about animals that migrate up to a mile high in the atmosphere and largely at night. Biologists usually cannot rely on simple means such as direct visual observation to unravel the mysteries of bird migration. Fortunately the same national system of weather radars that warns the public of tornadoes and severe thunderstorms allows biologists to observe the movements of millions of birds during migration.

Spring and fall migration begins at night about an hour after local sunset. Radar shows this onset of migration as a sudden eruption of radar echoes as millions of birds depart habitats across the landscape. The radar tells us where birds take off and we can identify which kinds of habitats supported high densities of birds during stopovers. For example, considerably stronger echoes are associated with forest habitat than the agricultural habitat that dominates much of Illinois. Radar even reveals birds departing specific forest patches, especially where such patches are islands of habitat in a sea of agriculture. In this way, radar can identify which habitats support exceptionally large numbers of birds during migratory stopover, valuable information for migratory bird conservation.

Radar shows little evidence that migrating songbirds organize themselves into traditional flyways or corridors. Rather, they form a vast migratory layer in the lower mile of the atmosphere during much of the night. They pass over Illinois in broad fronts, their behavior in the air probably determined more by wind and weather than any potential hazards posed by the landscapes below. Come morning, songbirds are as likely to find themselves over the plentiful forests of the Shawnee as they are the agricultural landscapes of central Illinois or the featureless expanse of Lake Michigan.

Songbirds over Lake Michigan at dawn must make landfall. After rising in altitude, presumably for a better vantage in search of nearest land, radar shows that a bird over Lake Michigan at dawn will engage in one of two behaviors depending on its distance from shore. Birds within 30 km (19 miles) will reorient or change direction toward the nearest shore. Such behavior may result, at least temporarily, in large numbers of birds arriving in coastal habitats before dispersing inland. Birds greater than 30 km from shore will continue flight along an unaltered route, relying on energy reserves to carry them to an unseen shore.

Although central Illinois poses none of the immediate risks of being over water at dawn, it is nonetheless a challenging landscape for a forest dwelling songbird seeking stopover habitat after a long nocturnal flight. Even before human settlement, forested habitat was never common in this area once dominated by tallgrass prairie. Today less than 5% of east-central Illinois is forested, down considerably from presettlement levels. As a result, migrants pack themselves into available forest habitat at more than twice the density they do in more forested places. Food in these forest patches is scarce, and birds struggle to gain mass in preparation for the next migratory push. However, because these scattered forest patches offer migratory songbirds the only food (although meager) and protection, their scarcity in the agricultural landscape is an argument for their protection.

We wish to thank Chicago Wilderness for supporting this research.

Robb Diehl, University of Illinois; Ron Larkin, Center for Wildlife Ecology

Largemouth Bass Virus: An Emerging Fish Pathogen

Nothing draws attention to problems with wild fish populations like a fish kill. In 1995, a kill of approximately 1,000 largemouth bass occurred in the Santee Cooper Reservoir of South Carolina, sparking a great deal of public and scientific concern. The usual suspects of heat stress, toxic substances, and known pathogens were suggested, but none were found to be involved. Investigations led instead (and surprisingly) to the discovery of a new virus, Largemouth Bass Virus (LMBV). Because no viruses had previously been associated with either systemic infection or epidemic mortality in wild largemouth bass, this finding generated considerable concern among fisheries biologists and anglers.

LMBV has since been classified as an iridovirus (family *Iridoviridae*), a diverse family of large DNA viruses that infect reptiles, amphibians, fish, insects, and a variety of other invertebrates. It is closely related genetically to viruses of ornamental aquarium fish. This close relationship suggests that LMBV may have originated from the introduction of an exotic (Southeast Asian) pathogen into North American waters.

LMBV has been documented only in the United States. Since its discovery in 1995, and through 2003, it has been found in 17 states (see map on facing page). The occurrence of the first LMBV-associated fish kills in the Southeast seemed to imply a westward and northward expansion from a southeastern epicenter. Fisheries biologists, however, are continually discovering LMBV in new locations, and its origins within the U.S. are still unclear. Interestingly, a virus genetically identical to LMBV was recovered from frozen bass sampled in 1991 from Lake Weir in Florida, four years before the South Carolina outbreak. LMBV has probably been around for some time. Because not all states have surveyed for LMBV, the geographic distribution of the virus is almost certainly more extensive than that shown in the map.

LMBV has been found both in populations of bass that have experienced documented fish kills, and in apparently healthy populations as well. Affected fish float to the surface and lose equilibrium prior to death, but show no external lesions. Hyperemia (increased blood flow, leading to darkened coloration) is occasionally seen, but is not consistently associated with infection. Internally, many (but not all) fish have inflamed swim bladders, a condition known as pneumocystitis. Neither the mechanism by which LMBV kills fish, nor its mode of transmission is known.

A central database for LMBV is being maintained by the U.S. Fish and Wildlife Service Warm Springs Regional Fisheries Center, in addition to the recently released National Wild Fish Health Survey Database. Preliminary results of these surveys indicate that the virus is highly prevalent both as a proportion of total samples tested within states (between 7% and 49%) and as a proportion of sites tested (between 22% and 75% of sites in states in which at least 10 sites were tested). Within lakes, the prevalence of LMBV appears to vary considerably from year to year, and may decline after a fish kill. Lakes positive in a given year appear to remain so, but conversions from negative to positive status have been documented.The emerging pattern is that LMBV tends to strike in summer months, possibly precipitated by stressors such as elevated temperature, low oxygen, and angling. LMBV-associated fish kills have not been reported to occur in lakes repeatedly sampled in consecutive years, but longitudinal observation has been limited to date. Although, lakes that do experience fish kills also suffer observable declines in angling catch-per-unit-effort and possibly in the proportion of large fish caught, these effects seem to be transient. LMBV, therefore, appears to be as variable over time as it is across space.

Whenever new pathogens are discovered, debate inevitably ensues as to whether the pathogen is truly new or whether surveillance and detection methods have simply improved. LMBV is no exception. LMBV could be a recently introduced exotic pathogen, or it might have existed unnoticed in the U.S. for years. Nevertheless, LMBV is an emerging pathogen in the sense that its political and scientific visibility is increasing.

One of the most vexing questions about LMBV, recognized by scientists and nonscientists alike, is why some populations of infected bass experience fish kills while others, also infected, remain clinically normal. Different populations of largemouth bass may possess different levels of resistance or susceptibility to LMBV. Host immunity may be important, as well as the genetic composition of different bass populations. Innate genetic immunity to the virus, as well as varying levels of inbreeding and outbreeding depression, could be involved. It is also possible that there are multiple strains of LMBV, each with varying degrees of virulence. Finally, environmental factors could interact with either the host or the pathogen (or both) to precipitate disease.

Unfortunately, too little is known about the pathogenesis, epidemiology, and natural history of LMBV to predict its future impact. Even if the virus does not kill fish outright, it could alter their behavior or physiology in ways that decrease a population's sustainability or its utility to recreational anglers. Given this fact that LMBV does not appear to be present everywhere throughout its range, it is best considered as a pathogen in the process of emerging. Its consequences have yet to be played out in full.

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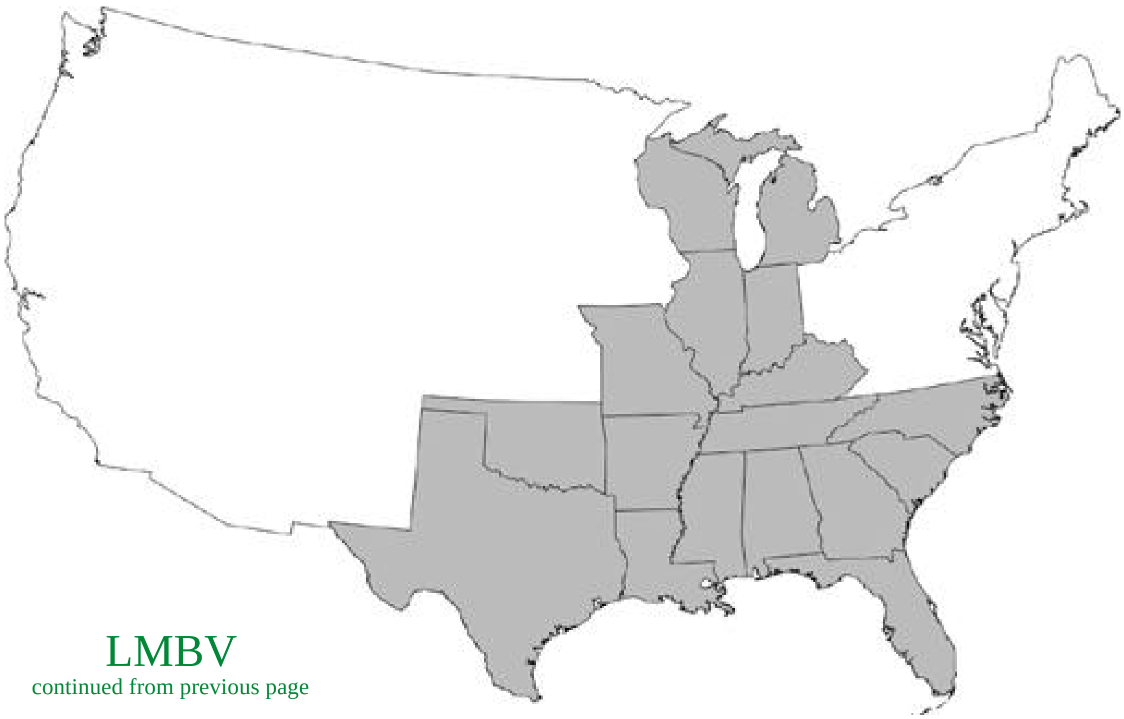

LMBV

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Perhaps the greatest concern is warranted not for the specific effects of LMBV, but rather for what the presence of this new pathogen may signify. Wildlife diseases appear to be emerging at an accelerated rate across the world. The growing consensus is that anthropogenic changes to the environment underlie this phenomenon. The pressures levied on wildlife by humans may account for the recent emergence of so many novel pathogens. If so, then LMBV may be an early indicator of a coming wave of health-related problems in which the sustainability of our wild fisheries declines by our own hand.

Acknowledgments

The ideas outlined in this article in large part reflect those of the participants in the 2001 and 2002 workshops on LMBV, organized by B. Shupp and the Bass Anglers Sportsman Society. Further discussions with J. Grizzle, R. Bakal, J. Plumb, A. Noyes, M. Conlin, J. Koppelman, S. Shults, and L. Willis were also highly informative. R. Bakal and J. Plumb provided helpful comments on the manuscript. Funding to support LMBV-associated research was generously granted by the Illinois Council on Food and Agricultural Research and by the Conservation Medicine Center of Chicago.

Tony L. Goldberg, Kate Inendino, and Emily Grant, University of Illinois; David P. Philipp, Center for Aquatic Ecology

Important Note to Subscribers

We are updating our mailing distribution list to *Illinois Natural History Survey Reports*. Therefore, we need to hear from all subscribers who would like to continue to receive *INHS Reports* in the mail. To assist our subscribers in this project, we will be sending each address currently on the mailing list a card through the mail in the near future. The card will request those who wish to continue receiving *INHS Reports* in the mail to fill out the card and return it the Illinois Natural History Survey by May 31. Postage for these reply cards is prepaid, so there will be no expense for those who choose to reply. However, only those subscribers returning the reply cards will be retained in the mailing database.We will assume that subscribers who do not return their cards either no longer wish to receive our newsletter via the mail or that their addresses are no longer valid.

Of course, whether they remain on the mailing list or not, readers of *INHS Reports* always have the option of accessing it on the Web at URL: http://www.inhs.uiuc.edu/chf/pub/surveyreports/sr-index.html

Species Spotlight

Striped Skunk

Susan Post

Imagine a mammal that runs slowly, has little endurance, and eyesight so poor that it has trouble picking out stationary objects over six yards away.

Striped skunk (*Mephitis mephitis*).
Photo from INHS Image Archives

How would it avoid becoming "easy" prey? If that mammal is the striped skunk, it has a potent chemical defense system that assures it will not be bothered.

The striped skunk, *Mephitis mephitis*, is found only in North America. Its range extends from central Canada to northern Mexico. In Illinois it is common and found throughout the state. While skunks use a wide variety of habitats, they prefer forest borders, brushy areas, and open grassy fields broken by wooded ravines and rock formations. Skunks can dig their own dens, but prefer to use those excavated by other animals such as woodchucks. Den sites include stumps, caves, rock piles, old buildings, junk piles, woodpiles, or dry drainage tiles.

Skunks are about the size of a domestic cat. They have triangular heads and are boldly marked. A skunk is glossy black except for a narrow white stripe on its nose and forehead and a wide white stripe on its back that divides into two stripes that continue part way over the back. The tail is long (6–15 inches) and fluffy. The total length of the animal, including tail, is 20–30 inches.

Skunks are generally solitary, although females will sometimes winter together in underground dens. In early spring males and females mate and the female will give birth in early May to four to eight blind, hairless kittens. At six weeks of age the young skunks will follow their mother single file into the woods to forage for food. They take the same route every night. The mothers are protective of the kittens during the early weeks and assume all training and feeding responsibilities. By the age of 10 months the juvenile skunks are full-grown.

A small, conical hole in a grassy area of lawn that has no dirt around it is a sign that skunks have been digging for grubs. Skunks will eat both plant and animal foods, but insects, such as bees, grasshoppers, and grubs, are preferred foods. They will also eat mice, young rabbits, voles, birds and bird eggs, corn, cherries, and even carrion (dead animals). During the fall skunks build a layer of fat. This layer of fat will provide energy for them during the winter when they spend most of their time sleeping in dens. Skunks are not true hibernators, as they will venture out of their dens if temperatures are above freezing.

Its scientific name comes from the Latin for "a poisonous vapor coming from the ground." The common name skunk is thought to come from the Abnaki Native American name segonky, meaning "he who urinates." Another common name is polecat, which is from an old French word meaning "fowl" or "hen," since skunks often raid the farm henhouse.

While several Illinois mammals have scent glands, the gland development is greatest in the skunk. The skunk's "poisonous vapor" is an amber, oily liquid stored in musk glands located at the base of the tail. The glands open to the outside through small nipples, which are hidden when the tail is down. The skunk has control over the glands, so the stream may be sprayed as a fine to a powerful stream of liquid beads. The chemical name of the musk is butylmercaptan. The odor molecules of this fluid are powerful enough to be detected through glass, plastic, and metal.

A skunk will give warnings before using its odor defense. These include arching its back, shaking its head, raising its tail, and stamping its feet. When these fail the skunk turns around with tail raised and takes aim. This defense is fairly successful except against domestic dogs, coyotes, badgers, and great horned owls, which kill a few skunks. Unfortunately, this defense does not work on vehicles or farm machinery, which are major sources of mortality.

Cherokee Native Americans believed that the scent of the skunk would keep away contagious diseases. A "scent bag" containing the odor was hung over the doorway and a small hole was pierced though the bag so the scent would permeate the room. If an epidemic was particularly bad, the entire body of the skunk was hung up, the meat cooked and eaten, and skunk oil rubbed over the skin. While the odor of the skunk may not contain natural chemicals that can combat contagious disease, the odor probably discouraged visits from those who may have been infected and helped stop the spread of the disease, making the stench effective in its own way.

Teachers Guide to "The Naturalist's Apprentice"

Notes for Teachers and Parents

Explain that if animals make errors in choosing a mate, they will not be able to reproduce. This would be a dead end. Injury or death may result if the wrong mate is chosen.

Closely related species occasionally produce hybrids (a cross of two different species). Include some scents that are similar (orange and tangerine slices, for example) and determine what percent of the population would make mistakes when picking a mate. Explain that most hybrids either die or are sterile (unable to reproduce themselves), so this would likely be a dead end. A common example of a hybrid is a mule, which is a cross between a horse and a donkey.

Classes can be divided into six groups, each representing one species, but each student must sniff and record his or her results individually.

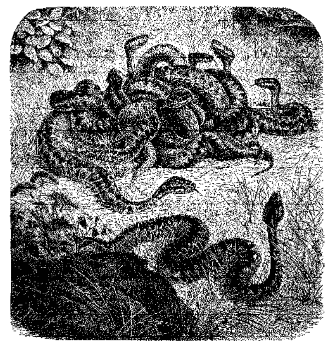
The Naturalist's Apprentice

Animals Make Scents

Carolyn Nixon
and
Michael Jeffords

Animals Make Scents—The Pheromone Game

Scents are important to animals in more ways than just defense. Different scents may be used to mark territory or attract a mate. Scents produced by an animal to give a chemical signal to other animals are called pheromones. Pheromones help many animals to find mates. To demonstrate how pheromones work, let's play the Pheromone Game.



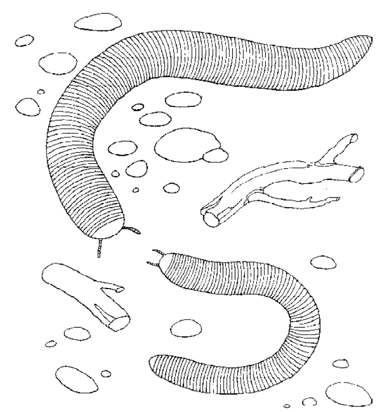
MATERIALS NEEDED

- 18 baby food jars with lids
- aluminum foil or black paint
- a punch or a sturdy nail and a hammer to punch holes
- 3 each of 6 different common food items with distinct odors: (examples include garlic, slices of lemon or orange, chocolate, peanut butter, cotton ball soaked with coffee or vanilla extract)

PROCEDURE

1. Cover each jar with aluminum foil or paint the jars black. Punch five or six holes into each jar lid. Number the jars consecutively, 1 through 18. Place a sample of one of the six items with distinct odors into each of the jars; replace the lids and number the jars. There should be three jars of each food item. Record which items are in which jars on a sheet of paper. Randomly place the jars about the room.

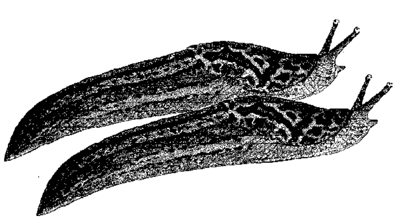
2. Write the names of each of the six items on separate slips of paper, one for each player.

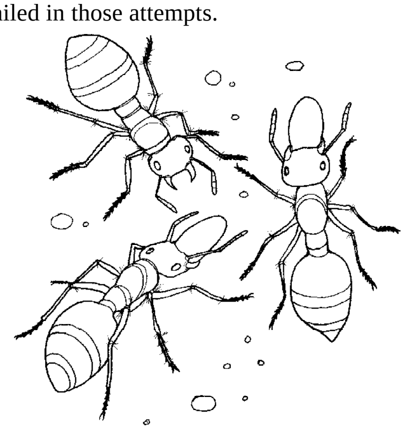


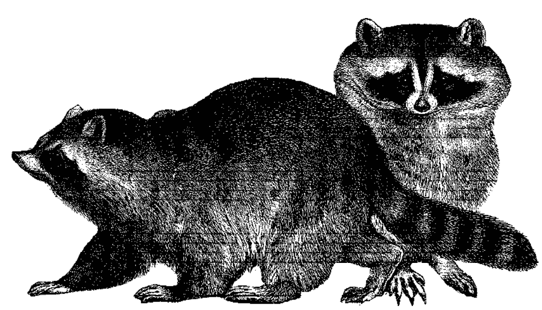
3. This is a silent exercise and no talking or other communication will be allowed. Ask each player to list the numbers from 1 through 18 on a sheet of paper and to carry this list and a pencil throughout the exercise. Show each player one of the six slips of paper; this is the special odor for which they are to search; no other odor is of interest to them. Players then sniff the contents of each jar and place an X opposite the numbers on their lists that correspond to the numbers on the jars that they think contain the special item for which they are searching.

4. After the sniffing has concluded, reveal the contents of each numbered jar so that players can check the accuracy of their noses. An accurate nose should have detected the same scent in three different jars.

If players successfully identified the correct scents, they would have been able to reproduce. If they made mistakes, they would have failed in those attempts.







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Organic Research

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colleagues at the University of Illinois on an Organic Task Force to provide greater focus on organic issues and to facilitate development of multi-disciplinary, cross-institutional research and education projects pertinent to organic systems. As part of its commitment, the Survey recently designated six acres at its Windsor Road site for long-term research on organic production systems. Survey and university scientists have teamed up to initiate a research program for this site, which will be developed following organic certification guidelines. Participants at present include specialists in vegetable entomology, crop protection, soil biology, weed science, composting, and soil organic matter. The initial research will focus on organic transition. Land must be free of synthetic chemicals for three years before crops grown there can be certified as organic. This period—when growers are transitioning from conventional practices that relied on synthetic chemical inputs for fertility and pest management—presents great challenges for organic producers but also great opportunities for exploration of the complex changes in the soil food web that occur during the transition. Research at the long-term site will compare organic systems differing in use of tillage, cover crops, and soil amendments to manage weeds and soil fertility, with more specific experiments conducted within each system. Additional acreage nearby is available for short-term projects pertinent to organic production. To ensure the relevance of the research to Illinois producers, the research team is seeking input from experienced organic growers to serve as an advisory panel to evaluate potential organic systems and specific experiments within each system. Results from this research, while emphasizing improvement of organic systems, will also have value for sustainable and conventional farm systems that are seeking ways of reducing inputs.

John Shaw, Cathy Eastman, and Ed Zaborski, Center for Economic Entomology; Michelle Wander, John Masiunas, and Dan Anderson, University of Illinois; and Leslie Cooperband, University of Wisconsin

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In Memoriam

Harold C. Hanson
1917–2003

Harold C. Hanson, retired Professional Scientist with the Illinois Natural History Survey, passed away March 17, 2003. Dr. Hanson graduated in 1940 with a B.S. degree from Luther College, received an M.Sc. degree from the University of Wisconsin in 1943, and earned his Ph.D. from the University of Illinois in 1958. No funeral or memorial service are planned.

Harold Hanson was the author or coauthor of more than 40 scientific publications, including studies of arctic birds and mammals, cottontail rabbits, Wood Ducks, diseases and parasites of ducks and geese, voles, Sharp-tailed Grouse, Canada Geese, and other topics. Several of his research projects reported results that were new directions for research or landmark works. These included techniques for determination of age and sex in birds, artificial propagation of captive waterfowl, bioenergetics of reproduction in birds, Mourning Dove ecology, use of feather minerals as biological tracers for determination of breeding and molting grounds of waterfowl, the importance of mineral licks to North American ungulates, and the identification of various races of Canada Geese. It was this last topic that consumed Dr. Hanson's later years as he worked on a multi-volume treatise *The White-cheeked Geese*. Dr. Hanson won The Wildlife Society's Terrestrial Publication Award in 1967 for his book, *Giant Canada Goose*, and the same award in 1978 for *The Biogeochemistry of Blue, Snow, and Ross' Geese*.

Dr. Hanson spent a number of field seasons in the Canadian Arctic where he became familiar with prominent Arctic explorers in the first half of the 20th century. He became a defacto expert in the diversity of land forms that compose the Canadian Arctic and spent many years studying the correlations among geology, climate, and Canada Goose evolution.

Dr. Hanson was an excellent photographer who enjoyed not only taking pictures but also enlarging and printing them in his darkroom. He photographed Olympic ski jumpers as a hobby. Recently he became excited by computers and digital imaging. He personally scanned hundreds of his photographs for use in his compendium *The White-cheeked Geese*.

A conversation with Dr. Hanson was seldom a short or simple affair. While his mind remained sharply focused on any topic that currently obsessed him, it also ranged widely on multiple tangents related to his focus. A question about goose migration could elicit comments from Dr. Hanson on flyways, goose evolution, evolution theory, the history of scientific thought, field experiences in the Arctic, customs of the Cree Indians, and personal scuttlebutt about other researchers and academicians whom Dr. Hanson had encountered in his long career. Coupled with his wry, and often scathing wit, every encounter with Harold Hanson was a feast of fact, fun, and fascination.

The world has lost a colorful and truly unique individual with Dr. Hanson's passing.