Ripple Marks

The Story Behind the Story

BY CHERYL LYN DYBAS

Winter Ice on Lakes, Rivers, Ponds

GOING, GOING, GONE? If you're planning to ice skate on a local lake or river this winter, you may need to think twice, according to scientists John Magnuson, Olaf Jensen, and Barbara Benson of the University of Wisconsin at Madison and their colleagues.

From sources as diverse as newspaper archives, transportation ledgers, and religious observances, the researchers have amassed 150 years of lake and river ice records spanning the Northern Hemisphere. Almost all show a steady trend of fewer days of ice cover.

If the pattern continues, only in Currier and Ives prints will ice skaters twirl across frozen rivers.

"Calendar dates of freezing and thawing of lakes and rivers were being recorded well before scientists began to measure these freshwater systems," said Magnuson. "These simple records provide a seasonally integrated view of global warming from regions where early temperature measurements are sparse."

The records show that later freezing and earlier ice breakup occurred on lakes and rivers across the Northern Hemisphere from 1846 to 1995. Over those 150 years, changes in freeze dates averaged 5.8 days per 100 years later, and changes in ice breakup dates averaged 6.5 days per 100 years earlier. The findings translate to increasing air temperatures of about 1.2°C each century.

Now the scientists have looked more specifically at trends in ice duration in 65 water bodies across what might be called the last bastion of winter in the United States—the Great Lakes region (Minnesota, Wisconsin, Michigan, Ontario, and New York)—

Photos courtesy of John Magnuson, University of Wisconsin at Madison

during a period of rapid climate warming (1975–2004). They published their results in the September 2007 issue of the journal *Limnology & Oceanography*.

Average rates of change in ice freeze and breakup dates on inland lakes were 5.8 and 3.3 times more rapid, respectively, than historical rates from 1846 to 1995 for the Northern Hemisphere. Average ice duration decreased by 5.3 days per decade in the recent study. Over the same time period, average fall through spring temperatures in this region increased by 0.7°C. The average number of days with snow decreased by 5.0 days per decade, and the average snow depth on those days decreased by 1.7 cm per decade.

"The formation and breakup of ice are important seasonal events in mid- to high-latitude lakes and rivers," the scientists wrote in *Limnology & Oceanography*. "The timing of these events—ice phenology—is sensitive to the characteristics of individual water bodies and to broader-scale weather patterns and climate variability."

Changes in ice phenology have important consequences for fish and zooplankton communities. Earlier ice breakup has created a temporal mismatch, for example, between the peak spring phytoplankton bloom and the population dynamics of some species of zooplankton. Fewer days of ice cover are also likely to reduce or eliminate winter kill in shallow eutrophic lakes.

In contrast to the general observation that climate changes are occurring more rapidly at higher latitudes, the greatest rate of change in ice breakup dates in the Great Lakes region is happening at lower latitudes, near the southern boundary of the area in which lakes are routinely ice covered during winter.

During the late 1980s and early 1990s, for example, ice breakup occasionally occurred in midwinter on two lakes in southern Michigan. These lakes previously hadn't seen open water until spring. By the end of the Great Lakes study period, in 1998 and 2002, several southerly lakes did not freeze over.

In lakes from Big Green in Wisconsin to Cranberry in New York, from Minnetonka in Minnesota to Gull in Michigan, winter—at least in the form of ice—is fast melting around the edges.

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The Tales Melting Ice Could Tell

ANCIENT MICROBES LOCKED IN GLACIERS MAY RETURN TO LIFE. "Valleys of the dead," Antarctic explorer Captain Robert Falcon Scott called them in 1905. Indeed, Antarctica's Dry Valleys are among the most desolate places on Earth. The ice-covered moonscapes seem freeze dried and completely lifeless.

But scientists Kay Bidle, SangHoon Lee, and Paul Falkowski of Rutgers University in New Brunswick, New Jersey, and David Marchant of Boston University, have found that these glacier-covered landscapes harbor tiny frozen organisms that have remained "alive" for more than a million years, encased in the oldest ice on Earth.

The microorganisms, buried in glaciers in Antarctica's Mullins Valley and Beacon Valley, may return to life as the ice sheets melt.

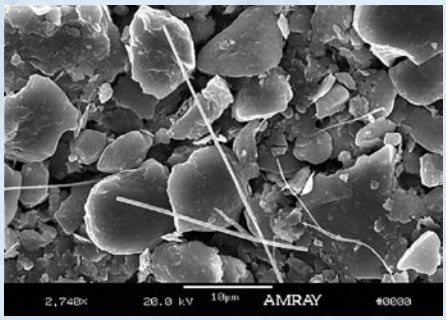
Until this discovery, reported in the August 14, 2007, issue of the journal *Proceedings of the National Academy of Sciences (PNAS)*, scientists didn't know whether such ancient microorganisms and their DNA could be revived, or for how long the cells would be viable after they had been frozen in ice.

The researchers melted ice samples ranging from 100,000 to 8,000,000 years old to find the microbes hidden within. "We found more microorganisms in the 'young' ice than in the 'old,'" said Falkowski. "The younger ones grew [in culture media] really fast. Microorganisms from the older-age samples grew very slowly, doubling only every 70 days."

The microbes in the oldest ice were not only slow to grow; the scientists weren't able to identify them during the growth process as their DNA had deteriorated. "There is still DNA left after 1.1 million years," said Bidle, "but 1.1 million years is the 'half-life.'" The average size of DNA in microbes in the oldest ice was 210 base pairs. The average genome of a bacterium alive today is 3,000,000 base pairs.

"Analyses of ice samples spanning the last 8,000,000 years in this region demonstrated an exponential decline in the average community DNA size," the scientists wrote in *PNAS*, "thereby constraining the geological preservation of microbes in icy environments."

Bidle and colleagues chose glaciers in Antarctica for their research because the polar regions are subject to more cosmic radiation than elsewhere on Earth. "Cosmic radiation is blasting DNA into pieces over geologic time," said Bidle. Most organisms can't repair the damage. Due to the deterioration of the microbes' DNA in the oldest ice, the scientists concluded that life on Earth, however it may have arisen, didn't ride in on a comet or other debris from outside the solar system.



Ice microbes. *Courtesy of Kay Bidle, Rutgers University*

"The preservation of microbes and their genes in icy comets may have allowed transfer of genetic material among planets," they wrote in *PNAS*. "However, given the extremely high cosmic radiation flux in space, our results suggest that it is highly unlikely that life on Earth could have been seeded by genetic material external to the solar system."

But resuscitation of microbes from Antarctic ice raises the question, said Bidle, of whether the microorganisms were preserved in ice in an inactive state, or were capable of in situ maintenance metabolism. Liquid water may exist in ice as microlayers around sediment grains or as microdiameter veins caused by ionic impurities in the crystal structure of ice, raising the possibility of metabolically active subpopulations, believe the scientists. The analytical procedures in their study, however, couldn't directly discern the presence of aqueous microlayers or in situ metabolism.

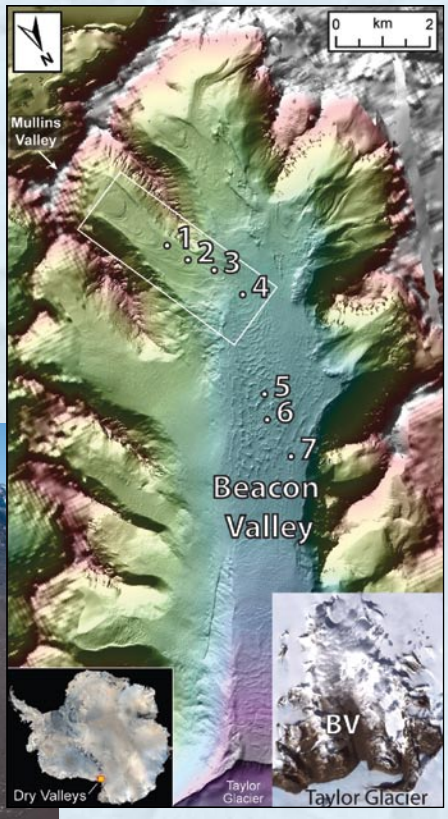
"Nonetheless," they wrote in their paper, "our 16S rDNA reconstruction may reflect a metabolically active subset of the encased bacterial population or at least those capable of preferential production of genomic DNA by an unknown mechanism."

Scott wrote in his diaries that the valleys of the dead were "a God-awful place."

For humans, maybe.

But oh, the microscopic tales of life—hidden and perhaps thriving—this icy realm could tell.

(Below) Beacon Valley and (right) ice sample locations. *Courtesy of Kay Bidle, Rutgers University*



Clams Make Food from Thin Air

Only plants can take nitrogen gas from the air and use it to make the protein they need to grow. Or so biologists thought. Now scientists at Ocean Genome Legacy in Ipswich, Massachusetts, and their colleagues at Harvard Medical School have shown that animals, too, can convert food into air.

The animals are marine clams called shipworms. They burrow into and eat wood, causing more than a billion dollars in damage to ships and piers each year.

"Wood has very little nutritional value," said biologist Dan Distel, executive director of Ocean Genome Legacy. "It contains almost no protein. But these clams use bacterial symbionts living inside a special organ in their gills to convert dissolved air (which is about 80% nitrogen) into the protein they need."

The discovery reveals a new way for animals to feed and suggests that other animals in the sea and elsewhere may be able to survive with only air as a source of protein. Understanding how these clams make use of this process is also helping researchers gain insights into how plants fix nitrogen, responsible for a large percentage of the protein made by plants and ultimately eaten by livestock and humans.

Distel and colleagues Claude Lechene and Gregory McMahon of Harvard Medical School and Yvette Luyten of Ocean Genome Legacy published a paper on their findings in the September 14, 2007, issue of *Science*.

Using multi-isotope imaging mass spectrometry (MIMS), they directly imaged and measured nitrogen fixation by individual bacteria in host cells, and demonstrated that fixed nitrogen is used for host metabolism. "This approach," said Lechene, "introduces a powerful new way to study microbes and global nutrient cycles."

Bacteria and archaea responsible for biological nitrogen fixation can be found in free-living form or in symbiosis with algae, higher plants, and some animals. Although these microbes are a critical part of the global nitrogen cycle, "there has previously been no means to evaluate this fixation process at a subcellular resolution," wrote Lechene et al. in their paper. "This is now possible with MIMS."

Wood and woody plant materials are abundant in the biosphere and are important nitrogen sources for fungi and microorganisms. But few animals are able to feed primarily on wood. Although rich in carbon, said Distel, wood contains two orders of magnitude less nitrogen per unit of carbon than does animal tissue. Animals using wood as food must therefore obtain other sources of combined nitrogen for biosynthesis. Wood-eating termites, for example, supplement their diet with nitrogenous compounds produced by nitrogen-fixing bacteria in their gut.

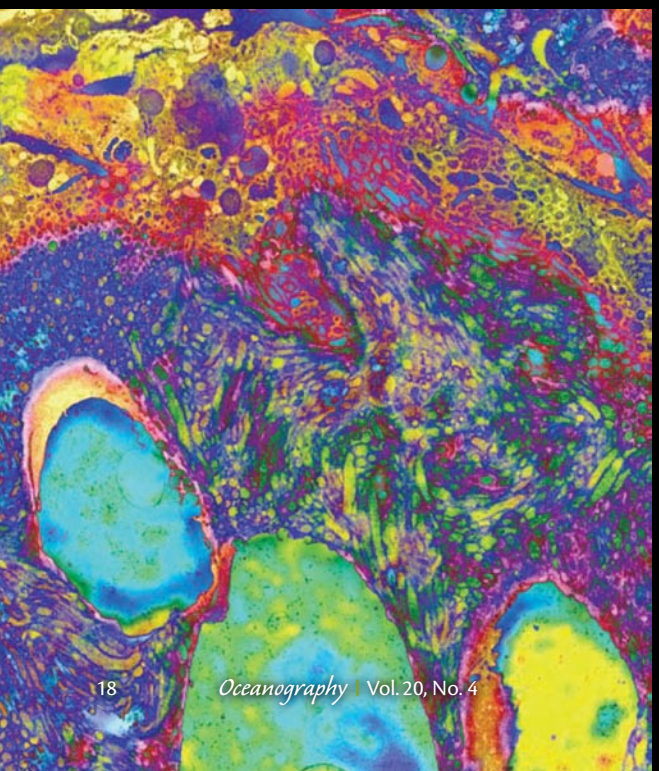
Along came shipworms, able to do the same thing.

"Although conspicuous communities of nitrogen-fixing bacteria have not been found in the guts of shipworms," said Distel, "dense populations of intracellular symbionts have been observed in cells in shipworm gills." A bacterium capable of fixing nitrogen gas, *Teredinibacter turnerae*, has been isolated from the gills of shipworms in the species *Lyrodus pedicellatus*.

Distel, Lechene, and co-workers localized and measured nitrogen fixation by individual cells of *T. turnerae* using MIMS to measure the incorporation of nitrogen gas enriched in the rare stable isotope ^{15}N. "MIMS technology has allowed us to localize, quantify, and compare nitrogen fixation in single cells and subcellular structures," said Distel.

Indeed, it turns out, animals—or at least this clam—can make food from thin air.

L. pedicellatus. Photo courtesy of Daniel L. Distel, Ocean Genome Legacy



This image depicts nitrogen fixation by individual bacteria within bacteriocytes in the marine bivalve *Lyrodus pedicellatus*. A color-coded image of $^{15}N/^{14}N$ has been overlaid on a transmission electron micrograph to show the accumulation and distribution of the stable isotope ^{15}N. Nitrogen-fixing bacteria are revealed by elevated $^{15}N/^{14}N$ ratios (green to brown). Field: 25 x 30 um. *Credit: National Resource for Imaging Mass Spectroscopy, Harvard Medical School and Brigham & Women's Hospital, Boston, MA*

Left photo. Steve Irwin and the Australia Zoo team capturing a croc. Right photo. Croc with a tracker. *Photos courtesy of Craig Franklin, University of Queensland*

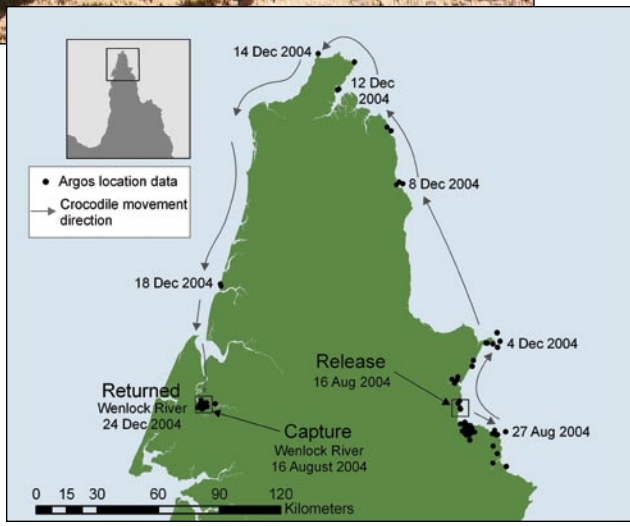
Out-Swimming an Estuarine Crocodile

DON'T TRY THIS AT HOME. Estuarine crocodiles, *Crocodylus porosus*, have a remarkable ability to find their way home, even across great distances, said biologist Craig Franklin of the University of Queensland in Australia. He and colleagues describe in a September 2007 paper in the journal *PLoS ONE* how they caught and tagged three large male "salties," as Franklin refers to them, transported the crocs 59, 99, and 411 kilometers, respectively, along the Australian coastline, then tracked their movements via satellite telemetry.

Co-authors of the *PLoS ONE* paper are Mark Read of the Queensland Parks and Wildlife Service; Gordon Grigg and Danielle Shanahan of the University of Queensland; and Steve Irwin of the Australia Zoo, the wildlife biologist known as "The Crocodile Hunter" who died last year after being fatally stabbed by a stingray barb.

After a short period of swimming around in new areas, all three crocs set off for home with "unnerving accuracy," said Franklin. The findings show the longest known "homeward bound" effort by a crocodile. "What we saw should make public officials think twice before moving dangerous saltwater crocodiles away from human settlements," Franklin believes. "It looks like they'll just swim straight back."

Crocs have a wide distribution, often in remote areas, and are secretive and easily disturbed by human presence, said Franklin. "Their capacity for large-scale movements has been poorly known. Ours is the first study of post-release patterns in translocated adult crocodiles, and the first application of satellite telemetry to a crocodilian."



Three large male crocodiles were captured in northern Australia and translocated by helicopter along the coastline, the longest distance stretching across Cape York Peninsula from west to east.

"All crocodiles returned rapidly and apparently purposefully to their capture locations," said Franklin. "The animal that circumnavigated Cape York Peninsula to return to its capture site traveled more than 400 kilometers in 20 days."

Such impressive homing ability is significant, say the scientists, because translocation is used to manage dangerous crocs inching ever closer to human settlements. "It's clear, though, that estuarine crocodiles can exhibit strong site fidelity, have remarkable navigation skills, and may move great distances, following a coastline as they go," said Franklin. "These long journeys include impressive daily movements of 10 to 30 kilometers, often consecutively."

It's noteworthy, said Franklin, that all three crocs spent a brief "stopover" time at their release points before making a beeline for home. Could the animals be gleaning information from local waters and thence going in the direction required?

"Our observations clearly indicate that crocodilians are skillful at interpreting a suite of complex cues for orientation and navigation," the biologists wrote in their paper.

If a problem crocodile lives near humans, options other than translocation need to be explored, the researchers believe.

For crocs as well as humans, there's apparently no place like home.

CHERYL LYN DYBAS (cldybas@nasw.org) is a marine scientist and policy analyst by training. She also writes on a freelance basis about the seas for *The Washington Post*, *BioScience*, *National Wildlife*, *Wildlife Conservation*, and many other publications.