



On thin ice. The wolves of Isle Royale are dwindling in number and face an uncertain future.

National Park. But some researchers argue that the study's value is so great and the current wolves so integral to the island that they warrant a "genetic rescue," by importing other wild wolves soon.

After discussions with geneticists, Peterson now leans toward this option as the "most beneficial, giving the best scientific return." But the fate of the wolves rests with the park service.

One for the books

The story is a staple of biology textbooks. Moose arrived on Isle Royale in the early 1900s, probably by swimming the 24 kilometers from the Ontario shore. Their numbers exploded on the predator-free island, and their browsing took a toll on the boreal forest. Then in 1949, a breeding pair of wolves crossed the frozen stretch of lake and began preying on the moose. The two populations began their scientific careers in 1959, when wildlife biologist Durward Allen of Purdue University and graduate student L. David Mech recorded the first numbers—20 wolves and about 500 moose—in what has become the world's longest running predator-prey study and one of science's most famous data sets.

The study has borne out some of ecology's fundamental tenets. It provided the first indisputable evidence that wolves hunt old and infirm moose or calves while leaving healthy adults alone. It was one of the first studies to show top-down control of a terrestrial food chain, by connecting wolf predation to the health of trees as seen in tree rings (*Science*, 2 December 1994, p. 1555). "Trees grew better when wolves were high and moose were low," Peterson says.

Since the pioneer wolves padded across an ice bridge to the island, the tale of Isle Royale has testified to the power of random events. "The significance of rare, unpredictable events is enormous," Peterson says, and often only understood in the long term. For example,

in the 1980s the wolf population crashed from its peak of 50 to a mere dozen (see timeline, p. 920). Years later, researchers found out why, detecting signs of deadly

ECOLOGY

Are Isle Royale's Wolves Chasing Extinction?

Wolves in an iconic predator-prey study are not producing pups, leaving scientists to confront a genetic rescue—or the project's demise

Since his graduate student days in 1971, Rolf Peterson has spent a few nights of every summer camped within earshot of wolf packs on Isle Royale, Michigan, in the northwestern corner of Lake Superior. It may be as early as the end of June that he hears the sound he's waiting for: high-pitched yips that stand out from the long, sonorous howls of adult wolves. The calls herald a new generation of pups joining the island's storied wolf population. For 40 years without fail, Peterson and his colleagues have heard those yips.

Until last summer. For the first time, the wildlife ecologist at Michigan Technological University in Houghton heard no yips in 2012, and failed to spot pups during the official aerial population count in January 2013. The lack of reproduction means that 2012 will likely go down as the beginning of the end of Isle Royale's wolves. The January count put them at their lowest number ever—only eight closely related individuals, down one from last year. The Michigan Tech team is on the island now and will listen intently for pups this summer, but Peterson

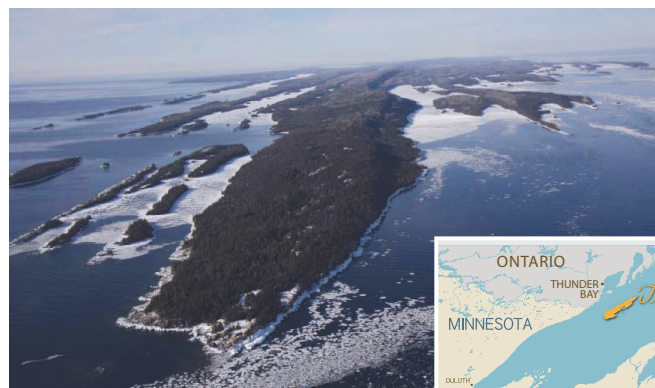
believes that inbreeding's pernicious effects have doomed the wolves. "It's over," he says. "It's just a matter of watching it wind down."

The surprise may be that the inbred population on the 544-square-kilometer isle has hung on this long, more than 6 decades after it was established by two or three curious wolves from nearby Canada. One school of thought has maintained that this chance natural experiment should run its course even if that means extinction, followed by a transfusion of fresh wolves to control the moose population on the rugged island, which is a U.S.

Online

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S Podcast interview with author Christine Mlot (http://scim.ag/pod_61355).



Science island. Isolated Isle Royale is home to the world's longest-running predator-prey study.

canine parvovirus in the wolves (*Science*, 27 August 1993, p. 1115). Even later, Peterson learned how parvo was likely brought to the island: A Minnesota veterinarian reported treating a parvo-infected dog that illegally visited the island on 4 July 1981. By 1990, the virus apparently burned itself out and disappeared from the island.

It's not just the wolves that have yielded scientific bounty: The moose, too, have been a research bonanza. Researchers and volunteers have packed out bones from close to 5000 moose carcasses, resulting in the world's largest collection. Together with bones from about 50 wolves, these remains have yielded insights on topics including forest health and moose arthritis.

For example, while teaching a dissection class, Peterson noticed that the club-sized lower leg bone of moose from the mainland seemed larger than what he was used to in Isle Royale specimens. His team has since shown that the size difference is significant and in a paper in press in the journal *Alces* will report that male Isle Royale moose have smaller antlers, too. In just a century on the island, moose have downsized to become among the smallest in the world. Thus, they are a classic case of another key biological insight: Large mammals shrink on islands, as did the miniature hippos and elephants that lived on Mediterranean islands during the Pleistocene. "On islands, big things get smaller," says evolutionary biologist Shripad Tuljapurkar of Stanford University in Palo Alto, California. The Isle Royale findings, he says, "provide good evidence that the island rule applies."

Inbreeding's insidious effects

Now that the wolf population has sunk to an all-time low, with just two remnant packs



Fresh stock. The immigrant "old gray guy" (center) reinvigorated Isle Royale's inbred wolves in the late 1990s.

instead of the historical three or four, this natural experiment in population biology and island biogeography is turning into a grim portrait of inbreeding depression: the reduced biological fitness that plagues tiny populations.

At least half of the eight wolves counted in January are female, according to DNA tests of scat, but the researchers detected less courting and mating than usual during their winter survey. The lack of reproduction may be because wild wolves typically avoid mating with close kin—and there are no other options on Isle Royale. Or, the wolves are mating but infertile because of genetic anomalies from inbreeding, or their offspring may not be viable.

In any case, it's clear that the wolves are racking up more and more physical abnormalities, probably from inbreeding. A 2009 paper in *Biological Conservation* reported that 58% of examined wolves had congenital spinal deformities, compared with only 1% of wolves in other populations. The abnormalities appear widespread—they turned up in all 12 wolves necropsied recently—but apparently are

not crippling, Peterson says.

Other observations bolster the argument that inbreeding is eroding the population's fitness. Researchers have noted wolves with one opaque, perhaps blind, eye. Also, an apparently healthy female died in her den in 2009 after delivering one pup, with her remaining seven pups dying in utero. That

had never been documented before in a wild wolf and may have ultimately stemmed from inbreeding, Peterson says.

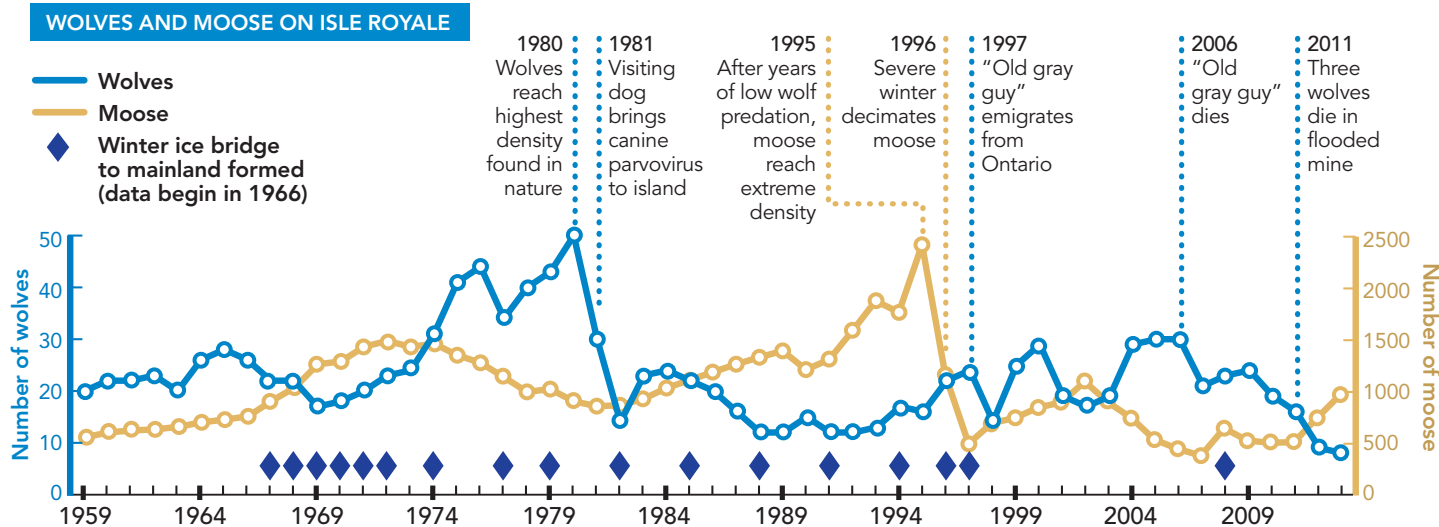
As dark as the outlook looks for the wolves, Isle Royale also offers compelling evidence of how to revive an inbred population. In 1997, in another chance event unbeknownst at the time to researchers, a large male wolf from Ontario crossed the ice bridge to the island. In 1998, the scientists spotted a striking animal—which project co-leader and Michigan Tech population biologist John Vucetich later nicknamed "old gray guy"—that became

whiter as he aged, something not seen before in Isle Royale wolves. But his provenance didn't become clear until after 2007, when Jennifer Adams, then a postdoctoral researcher at Michigan Tech and now at the University of Idaho in Moscow, extracted DNA from stores of frozen wolf blood, bone, and scat and analyzed it for key microsatellite markers to identify individual wolves.

The wolf DNA markers were rigged to fluoresce when exposed to a laser and recorded by software as distinctive peaks. As Adams ran the results for a marker on the



Inbred. Abnormalities such as an opaque eye and stillbirths plague Isle Royale wolves.



Y chromosome to identify males, she found a common peak representing one characteristic Y chromosome. As she ran the data for later years, a second peak suddenly appeared, representing a different Y chromosome marker. By the time she got to the 2003 samples, the first marker type had disappeared. When she constructed a family tree based on the genetic markers, the second type markers all traced back to one wolf.

Peterson and Vucetich went back to their field notes on the scat sample that had yielded the new Y chromosome: They had observed the old gray guy defecate at the site of a winter moose kill and had taken a sample. The new Y chromosome marker was independent corroboration of what researchers had noted in the field—the gray guy had taken over one pack as the new breeder.

Breed he did. After mating with a female and later with his own daughter, the old gray guy sired 34 offspring and genetically took over Isle Royale before his death in 2006. After a single generation, 56% of the genes in the population were his. His Y chromosome is now the only one present in the population. “Such a dramatic selective event influencing the whole genome has never been documented in a wild population before, as far as I know,” says Arizona State University, Tempe, population geneticist Philip Hedrick, one of Adam’s co-authors on a 2011 report on the phenomenon in the *Proceedings of the Royal Society B*.

Old gray guy’s appearance in 1997 “saved the population for another 10 to 15 years,” Peterson says. As wolf numbers grew, moose numbers fell, reinvigorating vegetation. “He had an impact on the entire forest of Isle Royale,” Peterson says. The immigrant also opened up a new research vein. University of California, Los Angeles, evolutionary biologist Robert Wayne and colleagues are now sequencing the genome of Isle Royale wolves before and after the old gray guy’s arrival, to see how inbreeding affects genome architecture and to compare mutations with those of outbred wolves.

Old gray guy’s new genes weren’t a cure-all, however. With the wolves dwindling once again, the population clearly could use another infusion of new blood.

But the odds are slim that more Canadian wolves will find their way onto Isle Royale. Temperatures in the region are rising with the changing climate, and the formation of winter ice bridges has become a once-a-decade event, instead of once every two to three winters as in the 1960s. Recent hot summers also seemed to be affecting the cold-adapted moose, which were down to about 385 in

2007. With wolves on the wane, however, moose are now waxing, from about 750 in 2012 to 975 at the start of 2013.

What to do?

Last winter, the researchers and the park service solicited input from geneticists about the wolves’ decline. But opinion on the path forward is divided. Citing successful genetic rescues of other populations, such as the Florida panther (*Science*, 24 September 2010, p. 1641), Hedrick and others advocate a similar operation on Isle Royale. Their argument rests on the wolves’ importance to the ecosystem and their influential scientific legacy. “It’s so incredibly rare to have such a long-term data set,” says conservation geneticist Lisette Waits of the University of Idaho. Advocates also note that the current wolves have cultural knowledge of the island. Although other populations hunt moose, Isle Royale is distinctive in that a single predator basically depends on a single prey. The population may not be genetically different from Ontario’s *Canis lupus*, but “I don’t think you should say they are just like every other population,” Hedrick says.

Vucetich is open to a genetic rescue and the lessons it could offer to other populations on the brink. Yet, he says there’s still a chance—a very small one—that the wolf population can come back on its own. “Isle Royale wolves are in the business of surprising us,” he says. Mech, now with the U.S. Geological Survey, notes that the recent moose decline could have delayed wolf breeding. With last winter’s moose calf boom, pups could still arrive in the next few years.

The park service generally takes a hands-off approach in wilderness areas, but it’s giving Isle Royale special scrutiny. The agency has assembled a team of national policy experts, local wildlife managers, and others to review the plight of the wolves in the context of how to treat the species in national parks as a whole. Options under consideration are to do nothing, bring in new wolves as soon as possible, or reintroduce wolves once the existing population dies off, which could happen in the next 5 years. The researchers are adamant that wolves are integral to Isle Royale’s ecosystem. “As long as there are moose on Isle Royale, there should be wolves,” Vucetich says.

Climate change is also a big part of the discussion, says Isle Royale park Superintendent Phyllis Green, who expects the team to recommend a course of action by fall. At that point, a public consultation will kick in, although anyone can weigh in now by sending comments to ISRO_Wildlife@nps.gov.

The park service decision will determine the fate of only a few animals on a remote island. But given the increasing number of isolated wildlife populations, Green says, this is “a national decision that will affect national policy.”



Moose multitude. With wolves scarce, moose numbers are up, which will add to the thousands of bones Peterson (above) and colleagues have collected over the years.

In the meantime, researchers and park visitors alike remain on watch. Earlier this month, volunteers on the project were lucky enough to spot three wolves hanging out on a frozen bay. The threesome probably was one of the packs, Peterson says—which means that the female isn’t curled up in a den with weeks-old pups. So the lucky sighting may bode ill for the wolves. Whether these wolves blink out, revive, or face another unpredictable game-changing event, observers on and off the island will be watching.

—CHRISTINE MLOT

Christine Mlot is a Wisconsin-based writer.