

► dates we get out of genetics are really quite embarrassingly bad and uncertain.”

Reich hoped that even if the meeting did not reach a consensus on mutation rate, it would highlight the research that is needed to move forward. He and Prüfer kicked off the meeting by polling attendees on their favoured rate, and found that the lower figure had gained popularity, but there was still a wide spread of opinions.

Increasingly, Reich and others conclude that the human mutation rate has fluctuated over millions of years. Much of the discussion at the meeting revolved around when it accelerated and decelerated — and why. Evolutionary changes in metabolism or reproductive biology are both possible causes. Aylwyn Scally, a population geneticist at the University of Cambridge, UK, thinks that the common ancestor of great apes, which lived between 20 million and 12 million years ago, had longer generations than its relatives on the monkey branch of the primate family tree. That would have slowed mutation: a longer generation would lead to fewer mutations per year, on average.

Medical-minded geneticists also fret about mutation rates. Meeting attendee Michael Stratton, director of the Wellcome Trust Sanger Institute in Hinxton, UK, is a cancer geneticist who studies the causes of DNA mutations. Environmental agents such as tobacco smoke trigger some cancers, but others are caused by the normal biochemical operations of cells — through processes that are little-known, says Stratton. Working out what these are could explain fluctuations in the mutation rate.

Reproductive biologists are also interested in the human mutation rate — in part because they have found that some diseases are more common in the children of older men than of younger ones. Sperm are produced throughout a man's life, whereas women are born with a full array of eggs. The constant division of sperm precursor cells means that men tend to pass on more new mutations to their offspring than women — four times as many, according to a 2012 estimate⁴ — and older fathers transmit more mutations than young ones. This means that changes in the biology of sperm production or paternal age over evolutionary time could influence mutation rate.

Even though the human mutation rate is still uncertain and unstable, Reich proposed at the meeting that researchers use the slower value for their work, at least until better data come along. Just don't think of it as a constant, he cautions: “This is not the speed of light. This is not physics.” ■

1. Scally, A. & Durbin, R. *Nature Rev. Genet.* **13**, 745–753 (2012).
2. Fu, Q. *et al. Nature* **514**, 445–449 (2014).
3. Lipson, M. *et al. Preprint at* <http://dx.doi.org/10.1101/015560> (2015).
4. Kong, A. *et al. Nature* **488**, 471–475 (2012).



The Grytviken whaling station on South Georgia island in the First World War. It has long been abandoned.

MARINE ECOLOGY

World's whaling slaughter tallied

Commercial hunting wiped out almost three million animals last century.

BY DANIEL CRESSEY

The first global estimate of the number of whales killed by industrial harvesting last century reveals that nearly 3 million cetaceans were wiped out in what may have been the largest cull of any animal — in terms of total biomass — in human history.

The devastation wrought on whales by twentieth-century hunting is well documented. By some estimates, sperm whales have been driven down to one-third of their pre-whaling population, and blue whales have been depleted by up to 90%. Although some populations, such as minke whales, have largely recovered, others — including the North Atlantic right whale and the Antarctic blue whale — now hover on the brink of extinction.

But researchers had hesitated to put a number on the global scale of the slaughter. That was largely because they did not trust some of the information in the databases of the International Whaling Commission, the body that compiles countries' catches and that manages whaling and whale conservation, says Robert Rocha, director of science at the New Bedford Whaling Museum in Massachusetts.

Rocha, together with fellow researchers Phillip Clapham and Yulia Ivashchenko of the National Marine Fisheries Service in Seattle, Washington, has now done the maths, in a paper published last week in *Marine Fisheries Review* (R. C. Rocha Jr, P. J. Clapham and Y. V. Ivashchenko *Mar. Fish. Rev.* **76**, 37–48; 2014). “When we started adding it all up, it was astonishing,” Rocha says.

The researchers estimate that, between 1900 and 1999, 2.9 million whales were killed by the whaling industry: 276,442 in the North Atlantic, 563,696 in the North Pacific and 2,053,956 in the Southern Hemisphere. Other famous examples of animal hunting may have killed greater numbers of creatures — such as hunting in North America that devastated bison and wiped out passenger pigeons. But in terms of sheer biomass, twentieth-century whaling beat them all, Rocha estimates.

“The total number of whales we killed is a really important number. It does make a difference to what we do now: it tells us the number of whales the oceans might be able to support,” says Stephen Palumbi, a marine ecologist at Stanford University in California. He thinks that 2.9 million whale deaths is a “believable” figure.

SOURCE: MAR. FISH. REV. 76, 37-48 (2014)

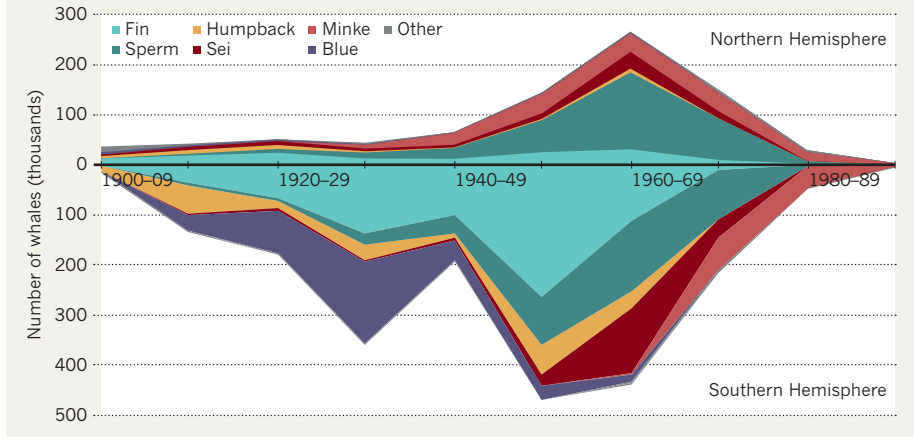
Sail-powered whaling ships took around 300,000 sperm whales between the early 1700s and the end of the 1800s. But with the aid of diesel engines and exploding harpoons, twentieth-century whalers matched the previous two centuries of sperm-whale destruction in just over 60 years. The same number again were harvested in the following decade. As one whale species became depleted, whalers would switch to another (see ‘The largest hunt’). Most commercial hunting was put on hold only in the 1980s.

“It’s an eye-opener for people to understand just how many whales were killed in the twentieth century alone. It shows how methodical and efficient whalers were,” says Howard Rosenbaum, a cetacean researcher who runs the Ocean Giants Program at the Wildlife Conservation Society, a non-governmental organization headquartered in New York City.

The latest estimate depended on detective work by Ivashchenko, who documented a huge illegal whaling operation in the Northern Hemisphere by the former Soviet Union for her 2013 doctoral thesis. Through interviews with former Soviet whalers and researchers, and reports from the whaling industry that she uncovered, she found that more than half a million whales had been caught by Soviet vessels, and that 178,811 of those were never declared to the International Whaling Commission.

THE LARGEST HUNT

Industrial whaling vessels killed nearly 2.9 million animals of various species in the twentieth century. Most were fin and sperm whales, but blue, sei, humpback and minke whales were also taken in their thousands.



Some researchers have used genetic data on certain populations to estimate how many whales existed before human hunting began. But the genetics has often suggested much larger original populations than the whaling records imply, says Rosenbaum. The estimates are now creeping closer together, he adds, as the genetics work improves and the catch data are revised upwards with inclusion of the true Soviet figures and other revisions. Understanding how

many whales were taken from the oceans might mean that targets that define when a species has recovered need to be changed, he says.

Rocha adds that 2.9 million whales is a lower bound. Although motorized boats were more efficient than the original sailing vessels in capturing whales, some of the animals they mortally wounded would escape or not make it onto official records. “The actual number of whales killed is going to be more,” he says. ■