https://news.mongabay.com/2021/04/sumatran-rhinos-show-low-inbreeding-but-when-it-happens-collapse-is-quick/

Sumatran rhinos show low inbreeding — but when it happens, collapse is quick

by Carolyn Cowan on 29 April 2021

- *Fewer than 100 Sumatran rhinos are believed to remain on Earth, and the species faces dire threats due to a low birth rate, habitat loss and fragmentation, and poaching.*
- *A new study finds that, despite its small size, the population retains significant genetic diversity, and likely has the genomic "toolkit" necessary to survive threats like climate change or disease.*
- *The findings are good news for conservationists, but also come with a warning: an analysis of a recently extinct subpopulation revealed that a rapid spike in inbreeding preceded their extinction.*
- *The research highlights dilemmas currently facing conservationists working to breed Sumatran rhinos in captivity: Should subspecies be mixed? And, when no alternatives exist, should captive rhinos be bred with their relatives?*

The outlook is bleak for Sumatran rhinos. Decades of poaching and habitat loss have precipitated a steep population decline. Once found across Southeast Asia, from the Himalayan foothills to the islands of Borneo and Sumatra, the critically endangered species, *Dicerorhinus sumatrensis*, is now only found in Indonesia. Conservationists estimate that fewer than 100 individuals survive in the wild, living in isolated pockets of forest.

Their rapidly diminishing population, extreme isolation from one another and poor reproductive success have raised fears that the remaining rhinos are likely to suffer from inbreeding problems associated with erosion of genetic diversity.

A new study, published this week in *Nature Communications*, affords rhino conservationists some respite. The study, led by the Centre for Palaeogenetics in Stockholm and an international team of researchers, revealed that the remaining populations of Sumatran rhinos in Borneo and Sumatra exhibit low levels of inbreeding and higher-than-expected genetic diversity.

"We were really surprised," says Johanna von Seth, a doctoral candidate at the Centre for Palaeogenetics and co-lead author of the study. "In terms of genetics, these are the best results we could have gotten."

It is good news for conservation management of the remaining populations, since it implies that there is still time to preserve the species' genetic diversity.

Love Dalén, professor of evolutionary genetics at the Centre for Palaeogenetics and co-author, says the findings suggest the remaining rhinos still have the "toolbox" to be able to handle disease threats and future changes in climate and the environment.

"It means that if we were to reverse the trend [of poaching and habitat destruction], and if we manage to get rhino numbers back up again, then hopefully we can preserve quite a lot of the genetic diversity, which is going to be very helpful for them in the longer run," Dalén said.

While the results may allow a sigh of relief, the researchers caution that it could be short-lived. They also looked at genetic patterns in a recently extinct rhino population on the Malaysian Peninsula. Findings indicate that these rhinos experienced a rapid spike in inbreeding prior to extinction that was likely due to small population size.

Piecing together the genetic puzzle

Scientists first sequenced the whole Sumatran rhino genome in 2017 using samples from Ipuh, a captive male who lived at Cincinnati Zoo where he sired three offspring. Ipuh's genome suggested that the species had relatively low levels of genetic diversity and that the world population of Sumatran rhinos peaked at around 57,800 during the most recent ice age. Thereafter, the population went into continuous decline, from which it has never recovered.

In 2017, researchers published results of mitochondrial DNA genome analysis, revealing information about when the three Sumatran rhino subspecies diverged. They found that the most recent common ancestor of the Sumatran rhino lived approximately 360,000 years ago and the subspecies began to diverge about 80,000 years ago, corresponding to major biogeographic events in the Sundaland region.

Of the three subspecies, two are still with us: the western Sumatran rhino (*Dicerorhinus sumatrensis sumatrensis*), found in Sumatra, and the smaller Bornean rhino (*Dicerorhinus sumatrensis harrissoni*). The third subspecies, which

used to roam as far afield as India and Bangladesh to northern Thailand, *Dicerorhinus sumatrensis lasiotis*, is now extinct.

The existence of the two extant subspecies on Borneo and Sumatra generates a conservation dilemma: with numbers dwindling to critically low levels, should the two populations be mixed to stave off inbreeding and genetic erosion?

Dalén's interest in Sumatran rhinos was sparked by his participation in a genomic study on the woolly rhino, *Coelodonta antiquitatis*. Sumatran rhinos are the extinct species' closest living relative, so his team first sequenced the genome of Kertam, a captive male Sumatran rhino then living at the Borneo Rhino Sanctuary in Malaysia, to use as a reference guide. Upon learning that Sumatran rhinos were themselves on the brink of extinction, Dalén launched a project to study their plight.

Kertam, or "Tam," a male Sumatran rhinoceros from Borneo whose genome was sequenced for this study. Kertam, who died in 2019, was the last known male rhino in Malaysia. Image by Scuba Zoo.

Low inbreeding, but a stark warning

To study levels of inbreeding and genetic variation in today's Sumatran rhino population, the research team sequenced genomes from 21 living rhinos and museum specimens, using Kertam's genome as a guide to map fragments of DNA from each sample to assemble each genome.

The comparatively low level of inbreeding in the present-day rhino population is likely due to the decline in population size having happened very recently: "Within a generation or two," according to Dalén. This means that inbreeding hasn't yet caught up with the rhino's current small population size.

However, the researchers also found that there are many potentially harmful mutations hidden in the genomes of these rhinos. Many of these mutations currently exist in a heterozygous inert state, but if inbreeding begins, the consequences could be severe.

"Unless the populations start increasing in size, there is a high risk that inbreeding levels will start rising, and consequently that genetic diseases will become more common", Nicolas Dussex, postdoctoral researcher at the Centre for Palaeogenetics who also co-led the study, said in a statement.

The team also revealed that the population of rhinos on the Malaysian Peninsula experienced a rapid spike in inbreeding levels just before it went extinct. Furthermore, the researchers found genetic patterns indicative of inbreeding depression, a phenomenon that is often found in small populations whereby closely related parents produce offspring that suffer from genetic disease.

"Maybe what happened in the Malaysian Peninsula population serves as a warning, an example of what might soon be happening in the other populations," Dalén said.

To mix or not to mix

The recent discovery of a wild female Sumatran rhino in Indonesian Borneo spurred discussions on how to stave off the effects of possible future inbreeding. Some experts advocate mixing the Bornean and Sumatran

subspecies, but this carries genetic risks associated with mixing populations that have adapted to completely separate environments.

“There is a risk that if individuals are translocated into a new environment, their genes are less well adapted to that new environment … you risk having worse genes spreading in the population, and as a consequence this decreases the population fitness, known as outbreeding depression,” von Seth said.

A comparison of the genomes from the Bornean and Sumatran subspecies found no evidence of local adaptation, which suggests that genetic exchange between the two groups would not harm either subpopulation. The researchers suggest that exchange of genes between Borneo and Sumatra is feasible, by either translocating individuals or using artificial insemination.

Alfred Roca of the University of Illinois at Urbana-Champaign, who led a 2018 study that looked at Sumatran rhino subspecies, advocates mixing the two remaining subspecies. “The numbers of the species are so low that I don’t see any alternative to joining any isolated animals from both islands into a single stock for captive breeding,” he said.

However, Terri Roth, a reproductive physiologist and vice president of conservation and science at Cincinnati Zoo, said that while the genetic results perhaps indicate breeding the subspecies would not be problematic, aspects of their basic biology do.

“The Borneo female is half the size of the male rhinos in Sumatra. The feasibility and potential challenges in breeding these two populations when the morphology is significantly different is something that requires serious consideration,” said Roth, who oversaw the captive-breeding program at Cincinnati Zoo. “Science is very important, but we also must pause to look at the animals in a practical way.”

Mother and daughter: Ratu (right) and Delilah (left), photographed in 2017 at the Sumatran Rhino Sanctuary in Indonesia's Way Kambas National Park. Delilah is now nearing the age of sexual maturity, but is closely related to all of the male rhinos at the sanctuary. Image by Jeremy Hance for Mongabay.

Wanted: More rhinos

Roth, who wasn't involved in the study, said the findings of the new study are excellent news. "When you have very small populations, you definitely worry about loss of genetic diversity due to inbreeding, but some populations shrink in size while still retaining sufficient diversity."

Sumatran rhino reproduction is excruciatingly slow. Immature rhinos must endure the relentless pressures of poaching and habitat loss for many years before they can breed. Females attain sexual maturity at 6 or 7 years old, and males at 10 years old. Furthermore, females only mate once every four or five years, and the species' gestation period is 16 months. Because of this, Roth said, the impacts on the Sumatran rhino's genetic diversity from inbreeding will take much longer to show up than in many other species.

Loss of fertility is a problem in the wild, where female Sumatran rhinos spend extended periods of time in a non-reproductive state due to the very limited chances of meeting with other rhinos.

In light of low natural birth rates and ever-decreasing numbers of rhinos, experts have reached a consensus that human intervention is necessary to stave off extinction. The Indonesian government, local and international experts, and conservation groups aim to boost numbers at captive-breeding facilities.

Currently, seven captive rhinos live in a sanctuary in Sumatra's Way Kambas National Park, including two breeding females, and one lone female is kept at the Kelian sanctuary in Indonesian Borneo.

Although information about levels of inbreeding is useful for such captive-breeding programs, its value depends on the status of the population. If there are plenty of animals in a population, conservation managers can choose suitable, unrelated mates. But if there are very few individuals, as in the case of the Sumatran rhino, then no such luxury exists.

"The importance of producing more offspring as quickly as possible far outweighs the value of avoiding inbreeding in most cases," Roth said. "If you only have close relatives, you breed them because you need the offspring or the species goes extinct. Besides, female rhinos will lose their fertility if you do not breed them for many years, so waiting for an unrelated male to show up is not recommended."

This is a predicament facing managers at the Sumatran Rhino Sanctuary. Delilah, a female rhino born there in 2016, is expected to reach sexual maturity this year. However, all three male rhinos in the captive-breeding program are related to her: her father, brother and uncle. Selecting the least-related male is the only option.

"In my opinion, the two highest priorities are to continue breeding the females currently in the managed breeding program at Way Kambas National Park and to capture a few more individuals to bolster this program by providing some unrelated individuals as mates for the calves already produced at the Sumatran Rhino Sanctuary," Roth said.

According to Zulfi Arsan, senior veterinarian at the Sumatran Rhino Sanctuary, plans are well underway to bring more rhinos into the program. Work is complete on new enclosures that could potentially hold up to five more rhinos. He said there are more options for pairing up a young male, Andatu, who was born under the program in 2012 and also reaches sexual maturity this year, since the females in the program come from a wide range of locations across Sumatra.

In this 2017 image, young Andatu has a breakfast of watermelon after being checked by keepers. Andatu made history as the first captive born Sumatran rhino in Indonesia when he was born in 2012. Image by Jeremy Hance for Mongabay.

Advanced techniques could help

One way to boost breeding success is to begin using such assisted reproductive technologies (ART) as artificial insemination. Although these technologies have never been successful with Sumatran rhinos, some experts say they have huge potential.

“In species with very small population sizes, genetic diversity erodes quickly,” said Alfred Roca. “The high diversity detected in the current generation emphasizes the need to collect cell lines and gametes from every surviving individual, whether wild or in captive breeding programs, so that their genetic diversity can be preserved and eventually restored to future generations of rhinos through advanced reproductive technologies.”

Rudi Putra has worked for more than two decades in northern Sumatra’s Leuser Ecosystem, thought to hold the highest number of Sumatran rhinos in the wild. He chairs the Leuser Conservation Forum and said he agrees that such techniques as artificial insemination will likely be an important tool for saving the Sumatran rhino in the future.

“Technology moves very quickly, so I am confident that ART will help with rhino breeding in time.”

Conservationists in the Leuser Ecosystem are now focused on capturing individuals from a small and fragmented population that has been heavily impacted by a slew of road construction throughout their forest habitat. Rhinos are particularly averse to crossing roads, which have effectively permanently confined them into smaller and smaller pockets of forest.

“This population shows no breeding evidence,” Rudi said. “We are trying to capture them to bring them into captivity at a new breeding facility that we are in the process of setting up.”

Alongside the local and central governments, conservationists have decided on the location of the new captive-breeding center in Aceh province at the northern tip of Sumatra. Rudi said he hopes newly captured rhinos will be able to contribute to the gene pool in the Way Kambas program in southern Sumatra. “In Leuser and Way Kambas, the [subpopulations] are similar, so potentially we could use both ART and transporting rhinos to breed naturally,” he said.

While genetics and advanced techniques cannot solve everything for the Sumatran rhino — ultimately, it is classical on-the-ground conservation that will produce results — Love Dalén said he hopes that genomic work like the new study can help out by bringing hope and providing conservation managers and captive-breeding programs with invaluable information about the relatedness of individual rhinos.

Citations:

- Von Seth, J., Dussex, N., Díez-del-Molino, D., Van der Valk, T., Kutschera, V. E., Kierczak, M., … Dalén, L. (2021). Genomic insights into the conservation status of the world's last remaining Sumatran rhinoceros populations. *Nature Communications*, *12*(1), 2393. doi:10.1038/s41467-021-22386-8
- Mays, H. L., Hung, C., Shaner, P., Denvir, J., Justice, M., Yang, S., … Primerano, D. A. (2018). Genomic analysis of demographic history and ecological niche modeling in the endangered Sumatran rhinoceros *Dicerorhinus sumatrensis*. *Current Biology*, *28*(1), 70-76.e4. doi:10.1016/j.cub.2017.11.021
- Steiner, C. C., Houck, M. L., & Ryder, O. A. (2017). Genetic variation of complete mitochondrial genome sequences of the Sumatran rhinoceros (*Dicerorhinus sumatrensis*). *Conservation Genetics*, *19*(2), 397-408. doi:10.1007/s10592-017-1011-1
- Brandt, J. R., Van Coeverden de Groot, P. J., Witt, K. E., Engelbrektsson, P. K., Helgen, K. M., Malhi, R. S., … Roca, A. L. (2018). Genetic structure and diversity among historic and modern populations of the Sumatran rhinoceros (*Dicerorhinus sumatrensis*). *Journal of Heredity*, *109*(5), 553-565. doi:10.1093/jhered/esy019