Fewer than 50 Sumatran rhinos are left in the wild, the International Union for Conservation of Nature says. The Indonesian government insists the number is larger.

rangers have supported such work on the ground, for example by counting orangutan nests, collecting elephant dung samples, and setting camera traps for tigers. But researchers say KLHK's headquarters has kept data from such efforts under wraps.

Wulan Pusparini, an Indonesian wildlife conservationist at the University of Oxford, says her DNA-based population survey has shown the elephant population in a national park in southern Sumatra declined by 75% between 2001 and 2015. Provincial BKSDA officials were "very supportive" when she presented those data in 2018, she says, "but it got stuck in Jakarta." KLHK's central office has not allowed her to publish the findings, Pusparini says.

In 2020, the Sumatran Elephant Conservation Forum, a consortium of scientists and conservationists from various NGOs and BKSDA offices, produced what it called an Urgent Action Plan describing remaining elephant populations, the threats they face, and how they could be protected. KLHK's director of conservation signed and released the document, but the ministry retracted it a year later. Among the reasons was what KLHK called "a counterproductive statement against the government" in the plan.

Studies on other species have met a similar fate. KLHK has not approved a consortium's estimate for Indonesia's tiger population, submitted in 2016; the data remain unpublished. ("It is the best available knowledge so far," says an Indonesian member of the team.) The ministry also disputes a recent report from a specialist group at the International Union for Conservation of Nature that estimates there are fewer than 50 Sumatran rhinos left in the wild. KLHK says it's between 67 and 75.

As for orangutans, the op-ed by Meijaard and his colleagues took issue with an upbeat assessment by KLHK Minister Siti Nurbaya on World Orangutan Day, on 19 August. The minister stressed Indonesia's commitment to conservation and said all three species in the country—including the Tapanuli orangutan, whose existence is threatened by a hydropower project in North Sumatra—would continue to "grow and thrive." The authors countered in *The Jakarta Post* that "A wide range of scientific studies … show that all three orangutan species have declined in the past few decades and that nowhere are populations growing."

KLHK did not respond to queries from *Science*. In a response published by *The Jakarta Post* on 26 September, however, a ministry spokesperson said Meijaard's analysis was based on "outdated information" and ignored many steps KLHK had taken to protect orangutans, including ending some concessions for new plantations. Nurbaya's assessment "was intended to build optimism," the rebuttal said.

KLHK has also blocked conservation initiatives. In late 2019, the ministry unilaterally ended a joint program in forest conservation with the World Wildlife Fund (WWF) after the organization criticized the government's handling of forest fires. The move forced WWF to lay off about 400 staff at offices across Indonesia. That same year, KLHK asked the Center for International Forestry Research in Bogor to retract a sobering estimate of the area burned during the fire season. As *Science* has reported (14 February 2020, p. 722), the spat led to the deportation of David Gaveau, a French landscape ecologist who worked with the center.

Some NGOs have chosen to adapt. PanEco, a Swiss-based organization, once campaigned against the Batang Toru hydropower project in North Sumatra, which poses a threat to the 800 or so remaining Tapanuli orangutans. It did an about-face in 2019 and decided to work with the Indonesian government and the company building the dam (*Science*, 13 September 2019, p. 1064). But a new population estimate produced by the group since then has not yet been released; a PanEco representative says it's up to the BKSDA office in North Sumatra to do so.

"This fear is doing real damage to Indonesian science."

Erik Meijaard, Borneo Futures

Meijaard says the Indonesian government should open up about the state of its biodiversity by making results from population and habitat surveys public and storing them in Indonesian and international databases. But with foreign researchers squeezed out and their Indonesian colleagues increasingly fearful, that seems unlikely to happen.

One Indonesian scientist says criticizing the government publicly could mean losing their job. "And it's not only about me, but about hundreds of people working in the same organization," the researcher adds. Since the *Jakarta Post* article, at least one-third of the Indonesia-based co-authors on an upcoming paper about orangutan conservation have asked Meijaard to remove their names, he says: "This fear is doing real damage to Indonesian science." ■

Dyna Rochmyaningsih is a science journalist in Palembang, Indonesia.

EVOLUTIONARY BIOLOGY

Secrets of Tibet's hot-spring snakes revealed

Mutations helped animals adapt to extreme temperatures, low oxygen

By **Elizabeth Pennisi**

Jia-Tang Li knows firsthand how tough life can be on the Tibetan Plateau. The air at 4500 meters is so thin that just a few steps take one's breath away. Despite bitter cold, the Sun is intense enough to quickly burn the skin. Yet the small grayish brown snakes this herpetologist at the Chengdu Institute of Biology at the Chinese Academy of Sciences studies have been thriving in the plateau's northern reaches for millions of years. The Tibetan hot-spring snake, *Thermophis baileyi*, keeps from freezing to death by hanging around the region's geothermal pools, feasting on frogs and small fish living there.

Now, advances in genome sequencing are giving Li and others a more detailed look at how the snake has adapted to its extreme environment. In recent work, his team has pinpointed genetic adaptations that may help the snake find waters that are just warm enough and withstand the low oxygen and intense Sun. Li's team has also reconstructed the snake's evolutionary history, work that could guide efforts to save these reptiles as they face ever-greater threats from humans.

"This is a pretty extreme place for snakes to be living," says Sara Ruane, a herpetologist at the Field Museum. The work "just shows how adaptable snakes are." Says Alex Pyron, a herpetologist and evolutionary biologist at George Washington University: "For reptiles, we generally assume if it's too cold, there won't be any snakes or lizards. Not so fast, says *Thermophis*!"

Although the Tibetan Plateau has more than 100 species of snakes, *T. baileyi* is the only one that lives at about 4500 meters. Two other hot-spring snakes, the Sichuan hot-spring snake and the Shangri-La hot-spring snake, live at lower elevations and are less dependent on the hot springs, says Song Huang, a herpetologist at Anhui Nor-

Tibetan hot-spring snakes exploit geothermal pools to survive at a high altitude.

mal University. Other snakes, including a pit viper, exist even higher, "but the key difference is that they are predominantly found at lower elevations," says Anita Malhotra, a herpetologist and molecular ecologist at Bangor University.

For snakes, "The outside temperature is very influential on the body temperature," says Justin Bernstein, who studies snake evolution at the University of Kansas, Lawrence. To withstand air temperatures that can drop below –20°C, the snakes lurk near the edges of geothermal pools reaching 40°C and hibernate. But the warmth brings challenges of its own. "Being a hot snake at high altitude is physiologically challenging," says Raymond Huey, a physiological ecologist at the University of Washington, Seattle, because the warmth boosts the snakes' need for scarce oxygen.

Between 2015 and 2018, Li led teams to the plateau to capture snakes and collect blood or small bits of tissue from the tip of the tail for sequencing studies. Because the snakes are rare and typically active only between 11 a.m. and 3 p.m.—if the Sun is out—the researchers could go days without seeing one, Li recalls. Their initial, incomplete genome, published in 2018, revealed mutations in genes that enhance breathing, make red blood cells more efficient, and make the heart beat more powerfully—changes that may help the snakes cope with low oxygen. Some of the same genes have also changed in yaks, pikas, ground tits, and other species that live at high elevations, albeit in different ways, he and his colleagues reported later.

That study also identified genetic changes in response to intense sunlight on the plateau, including modifications to genes whose proteins help repair DNA damaged by ultraviolet radiation. More recent work, reported on 3 September in *The International Journal of Molecular Sciences*, builds on those findings by showing at least two of those genes—*ERCC6* and *MSH2*—are also altered in a lizard living on the Tibetan Plateau and other high-altitude animals. "There seems to be a very predictable subset of genes … involved in high altitude adaptation," says Todd Castoe, an evolutionary biologist at the University of Texas, Arlington.

A more complete genome published on 1 August in *Innovation* shows how the snakes cope with another challenge: finding bathing spots that are comfortable but not too hot. Li's team compared genes involved in temperature sensing in hot-spring snakes and other organisms, including snakes such as rattlesnakes and pythons that hunt by sensing heat. They found that a gene called *TRPA1* is mutated in both the hot-spring and heat-sensing snakes.

TRPA1 encodes an ion channel that opens and closes in response to temperature changes, setting off a cascade of signals that can be relayed to the brain or to other parts of the snake's body. In rattlesnakes and pythons, changes to *TRPA1* lower the activation temperature of the channel, improving the snakes' ability to detect warm prey. In hot-spring snakes, biochemical tests by Li's group revealed, different changes to the protein ensure the channel opens up very quickly and completely.

What this means for the snake isn't yet clear, but Li suspects the changes might help it orient toward warmth. In behavioral experiments reported in the new paper, his group found that given a choice between a cold rock and a warm one, hot-spring snakes chose the warm rock more often and more quickly than did two other snake species that don't live at high elevations.

"These snakes are probably walking a really fine line between not freezing to death and not boiling," Castoe points out. The threat of scalding seems to have shaped other genes: Li's group found heat shock proteins, which repair proteins damaged by heat, have undergone accelerated evolution in the hot-spring snakes.

Climate history has also left a mark on the snakes' DNA. Li's team sequenced the genomes of 58 Tibetan hot-spring snakes collected in 15 places spanning about 500 kilometers. DNA differences pointed to three distinct populations that roughly coincide with three geothermal regions across the northern plateau. The pattern is the handiwork of past ice ages, Li and colleagues argue in the 7 September issue of *Molecular Ecology*. The westernmost group split off from the rest of the species during a major ice age between half and three-quarters of a million years ago; then the central and eastern populations were divided 300,000 years ago when another ice age threw up a new barrier of cold, isolating each group or snakes near its hot springs. "The thermal springs allowed them to get through the ice ages," Ruane says.

The isolation also led to unique adaptations in each group. For example, several genes for processing selenium and for metabolizing sulfur have evolved rapidly in the western group, possibly to deal with the specific chemistry of hot springs there, Li suggests.

Even though the three groups intermix occasionally, they are unique enough that "I would consider each a species," says Frank Burbrink, a herpetologist at the American Museum of Natural History. (Li and Ruane aren't convinced they're that distinct.) Each, Burbrink thinks, needs to be conserved separately.

Yet populations are declining. "Human activities have seriously affected the survival of Tibetan hot-spring snakes," says Huang, who collaborated with Li on the *Molecular Ecology* paper. In some places, construction has destroyed dens where these reptiles spend the winters. In other places, development has ruined wetlands that act as nurseries for newly hatched snakes. In May 2023, Huang and colleagues hope to begin to build artificial snake dens, restoring the wetlands and fencing people out of these sensitive spots.

The snakes, it seems, are exquisitely adapted to harsh nature—but not to the pressures that humans bring. ■

PHOTO: JUN-FENG GUO

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