

Zebras without borders



“If they arrive before water is available, they’re in trouble.”

Pieter Beck

Woods Hole Research Center

By Agnieszka Gautier

Hot air lolled with anticipating rain. This was September in Botswana, a time when rising temperatures stack mushroom clouds high into the atmosphere. Hattie Bartlam-Brooks, a field

researcher from the University of Bristol in the U.K., stood on top of a jeep, pointing an antenna into the savanna grasslands. She attempted to download Global Positioning System (GPS) data from her collared zebras, tracking their movement within the Okavango Delta. Then the sky



Zebras stripes come in different patterns, unique to each individual. They are social animals that live in harems. Here two stand in the Okavango Delta, Botswana. Unlike horses or donkeys, zebras have never been truly domesticated. (Courtesy M. Munneke)

split with a thunderous crack, signaling the first rains of the wet season.

But she couldn't find any of the seven tagged zebras. "They disappeared," she said. "Six months later I found them." Downloaded data reported the zebras had been deep in the Makgadikgadi Pan, 300 kilometers (190 miles) southeast of the delta, partaking in the pan's lush, sweet grasses during the wet season. That year, 2007, brought a huge surprise, and with it great hope for conservationists connecting ancient migratory routes.

Divided they stand

"Everyone thought migration had stopped," Bartlam-Brooks said. In the 1960s, most European colonial powers left Africa carved up by political boundaries, ignoring tribal and natural patterns. Botswana, a flat, landlocked country, protected its cattle industry against wildlife spreading disease with hundreds of miles of fences. With the fences up the zebras stopped migrating. But as the country matured it discovered tourism and removed most northern fences, freeing up large game reserves. Then migration re-established itself, but how? "None of the zebras had been to Makgadikgadi Pan before," said Gil Bohrer, a professor at Ohio State University and a lead for the NASA Movebank project, which links animal tracks to remotely sensed ecological data. "Not only that, migration restarting at all has never been shown before," Bartlam-Brooks said.

Anecdotal stories told of migration prior to the fence, but in the wild zebras do not live past their teens, and since the fence had been up from 1968 to 2004, there is no way they could have learned the route. "It's not that they followed their mothers as baby zebras and saw the saltpan," Bohrer



Baobab trees are scattered on Kubu Island, a dry granite rock island located in the Makgadikgadi Pan. Baobabs store water in the trunk to endure harsh drought conditions. (Courtesy abi.bhattachan/Flickr)

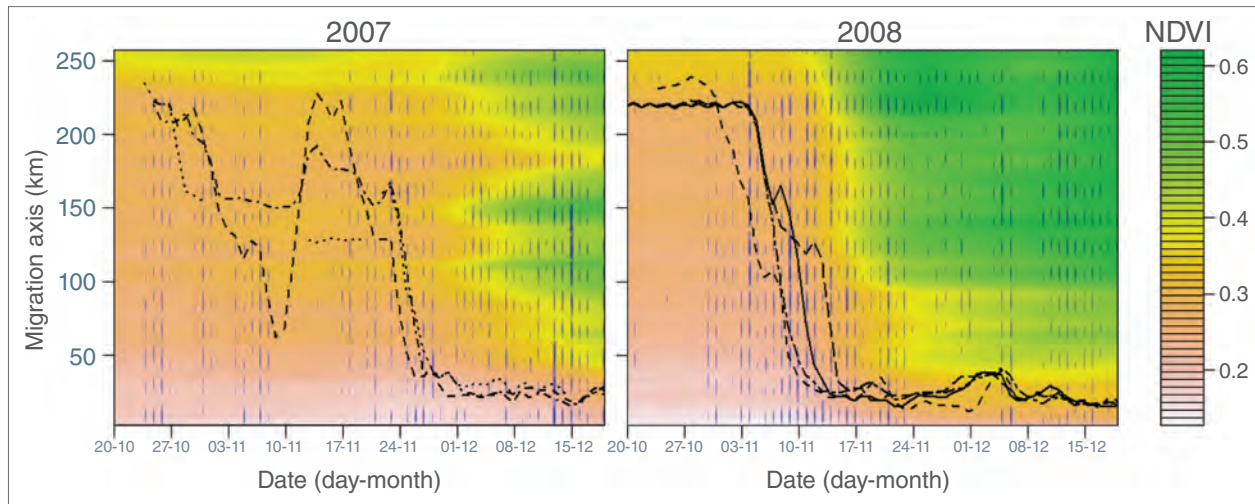
said. "Three or four generations lived behind the fence."

No compelling reason drives the zebra out of the delta. The Okavango River spills into the Kalahari Desert sand, calmly etching its tentacles into a delta that leads to nowhere, no river or ocean, just more sand within reed-lined riverbeds. Verdant year round, it supports herds of elephants, wildebeests, buffalo and hippopotamus, lone predators like cheetahs and leopards, the barely surviving African wild dog, hundreds of birds, and harems of zebras. It can sustain life year round. And the route from the delta to the

Makgadikgadi is desert, no water except for rain-filled waterholes. So why leave?

Basic instinct

"There is somehow, some knowledge within the zebra that sends them there," Bohrer added, referring to the Makgadikgadi. During the dry season, roughly April through May, water pools evaporate, leaving a scorched land. A salt crust gleams in the light, reflecting off the white horizon. Patches of grasslands interrupt the saltpan. And with the arrival of the rains, amidst palm trees, the grass becomes lush and extensive. But there is no permanent water here. Zebras can



The above figures depict zebra migrations from the Okavango Delta to the Makgadikgadi at the onset of the rains in 2007 and 2008. The Okavango Delta is at the top of the graphs and the Makgadikgadi is at the bottom. Different black lines indicate the movements of individual collared animals, three in 2007 and four in 2008. Blue vertical dashes indicate satellite-observed rainfall in the region during the migration. The figure on the left shows the retreat of one collared zebra when greening was not sufficient in 2007. Greening data is shown in yellows and greens, based on Normalized Difference Vegetation Index data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the NASA Aqua and Terra satellites. Rainfall data are from the NASA Tropical Rainfall Measuring Mission. (Courtesy H. Bartlam-Brooks et al., 2013, *Journal of Geophysical Research*)

only utilize the high-quality grasses when rains fill the pans and natural waterholes. When they dry up, the zebras return to the delta.

There are false starts to the seasons, however. So how do the zebras know when to go? “It was interesting for us to figure out the cues of migration,” Bohrer said. “And with the lack of ground-based data, you go to remote sensing.” A unique opportunity for remote sensing had presented itself—for the first time, it could be used to model the initiation of migration and the speed of travel. “Animal movement science has moved forward in leaps and bounds since GPS technology became affordable and widely available,” said Pieter Beck, a researcher with the Woods Hole Research Center in Massachusetts. “To all but the smallest land animals, you can strap GPS

and get data back.” Not only that, NASA instruments have improved, producing images at an ecologically relevant resolution.

People often think the animals migrate when the rainy seasons begin, but what is the exact cue? “Do they sense how much rain accumulated?” Beck asked. “Do they leave with the first big thunderstorm? Do they leave before it? Do they respond actually to the vegetation, which itself responds to the rainfall? And then, how do they pace themselves when on the move?”

On the move

The researchers focused on two environmental variables that remote sensing could easily measure: vegetation and rainfall. They obtained data on the productivity of the grass from Normalized

Difference Vegetation Index (NDVI) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the NASA Terra and Aqua satellites. They combined NDVI with estimates of precipitation from the Tropical Rainfall Measuring Mission (TRMM) satellite. “Between the precipitation, a direct cue, and the greenness of grass, which is a more sophisticated cue, meaning zebras need to project grass growth and respond to it,” Bohrer said, “we can determine the environmental cues that send them on their way.”

But could this environmental data actually predict the zebra’s movement—the migratory inception, and zebra speed and direction? To answer the question, the researchers created several models of increasing complexity, using data from 2007 and 2008, the years GPS information was available. At the simplest level, the model assumes that zebras start on a fixed date and migrate with a fixed speed. “That’s it,” Bohrer said, “They don’t care about the environment; they just know the date.” Timing as a migration trigger is possible considering that the sun is a good indicator of time. The accuracy of predicted zebra location ended up being quite high for such a simple model, 67 percent. “For observations in wild animals that move in complex and unpredictable ways,” Bohrer said, “it’s actually a crazy high number.” Still, do zebras use other cues? The researchers wanted more. “Can we get more accurate?” Bohrer asked.

The next model included cumulative precipitation, using TRMM data that Beck processed between the delta and the Makgadikgadi. The zebras feel enough rain, and then move. The final model added the speed of movement as a function of NDVI and precipitation rate. “So if it’s raining strong, they can actually walk slower,” Bohrer said. “If it’s very green around them, they



Botswana is home to the second largest zebra migration, following the Serengeti. About 25,000 zebra journey the 190 miles between the Okavango Delta and the Makgadikgadi Pan. Zebra perform an important ecological function as grazers, eating the longer strands of grass that then expose shorter growth, allowing wildebeest easier access to their source of food. (Courtesy R. Toller)



Hattie Bartlam-Brooks collars a zebra with Global Positioning System (GPS) to track its location along the re-established migration route from the Okavango Delta to the Makgadikgadi Pan. (Courtesy Botswana Herbivore Research)

walk faster.” They want to hurry up and get there because the vegetation is ripe. If it’s raining hard, they can pace themselves because the water will linger. “But those are just anthropomorphic interpretations,” Bohrer said. “I don’t know why they do that, but I know for a fact putting these

two variables in the models increases predictive accuracy of zebra location to 92 percent, which is very, very accurate.”

So some ancient instinct seems to lure the zebra to the grass, telling them when and how and

where to go. They wait until the rain reaches a certain threshold and then walk at a speed that is modified by the greenness and the rain. “Zebras are fascinating,” said Bartlam-Brooks, who went to the bush to study the animals on their turf. “I am amazed by their memory of the environment. They can follow highly directed routes to water or new grazing with minimal environmental cues—there are no hills, mountains in Botswana, yet they can orientate themselves in thick woodland or arid shrub over hundreds of kilometers.”

Within borders

Understanding the cues that drive such long-distance movements is critical to understanding the fate of migrations with climate change. Climate change models predict the deserts of Southern Africa will be drier more frequently. Migrations may be less successful because the zebras’ instincts will be off. “According to models,” Bartlam-Brooks said, “unsuccessful migrations will lock out the more susceptible portions of the population, so juvenile recruitment will decrease, the number of youngsters surviving the first year will drop, and that could affect population success.” At the same time, zebras adjust.

The desert, like most places on Earth, is governed by microclimates. Just because it started to rain in the Okavango Delta does not necessarily mean the Makgadikgadi pan is green. Beck studied the correlation between the cumulative precipitation in the Okavango Delta and the timing of the greening in the Makgadikgadi pan. “If they arrive before water is available, they’re in trouble,” Beck said. In most years, the cumulative precipitation in the delta predicts the greening in the Makgadikgadi pan, but there are specific years of drought and intense rain, which are typically El Niño/La Niña years, when those predictions fail. “These years are very hard for them,”

Bohrer said. “What they think should work, doesn’t.” 2007 proved to be one of those years. Initial rainfall in late October did not sustain into mid-November, delaying greening until early December. That year, zebra returned to the Okavango Delta, proving their resilience.

“Migrations are under threat everywhere, mostly due to habitat loss and conflict,” said Bartlam-Brooks. In Africa, where different countries establish their own wildlife policies, cooperation for their preservation can prove challenging. But this study brings great hope with it. In areas that were once joined and then broken up, many have said there is no point in reconnecting the lands. “Actually it’s not true,” Bartlam-Brooks said. “You can take down a physical barrier that’s been up for decades, and the animals do reconnect to ancient migratory routes successfully.” Wildlife knows nothing about borders, but now inter-system management across Africa may be able to develop conservation corridors and design routes for migration.

To access this article online, please visit <http://earthdata.nasa.gov/sensing-our-planet/zebras-without-borders>



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About the remote sensing data

Satellites	Terra and Aqua	Tropical Rainfall Measuring Mission (TRMM)
Sensors	Moderate Resolution Imaging Spectroradiometer (MODIS)	TRMM Microwave Imager
Data sets	Normalized Difference Vegetation Index (NDVI)	TRMM Daily Rainfall
Temporal coverage	16-day cycle	Daily
Parameters	Normalized Difference Vegetation Index (NDVI)	Precipitation rate
Data centers	NASA Land Processes Distributed Active Archive Center (LP DAAC)	NASA Goddard Space Flight Center Earth Sciences DAAC (GES DAAC)

About the scientists



Hattie Bartlam-Brooks is a research associate for the University of Bristol and lives in Maun, Botswana. She is interested in how resources determine herbivore movement and distribution patterns and how these are affected by anthropogenic factors. The Leverhulme Trust and the Wilderness Trust supported her research. (Photograph courtesy C. Bartlam-Brooks)



Pieter Beck is an ecologist at the Joint Research Centre of the European Commission who specializes in remote sensing and modeling of vegetation. He studies the effects that disturbance and climate have on the phenology, distribution, and carbon dynamics of vegetation as well as the associated land-atmosphere feedbacks. NASA supported his research while at the Woods Hole Research Center (WHRC). (Photograph courtesy WHRC)



Gil Bohrer is an assistant professor for ecological engineering at Ohio State University. His interests involve the development of physical and empirical models to link individual biological organisms to atmospheric processes. NASA and NSF supported his research. Read more at <http://goo.gl/k3Qr6s>. (Photograph courtesy G. Bohrer)

Maryland USA: NASA Goddard Earth Sciences Distributed Active Archive Center. <http://disc.sci.gsfc.nasa.gov/TRMM>.

For more information

NASA Land Processes Distributed Active Archive Center (LP DAAC)
<http://lpdaac.usgs.gov>

NASA Goddard Space Flight Center Earth Sciences DAAC (GES DAAC)
<http://daac.gsfc.nasa.gov>
Moderate Resolution Imaging Spectroradiometer (MODIS)
<http://modis.gsfc.nasa.gov>
Tropical Rainfall Measuring Mission (TRMM)
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