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Thieves in the Night
Elephant crop-raiding in Botswana

Kruger National Park
Partnership, perception, and poaching

Reconstructing History
A century of African lion conservation genetics

Oil, Gas, Wildlife, & Communities
Capacity building and mitigating conflict in Uganda

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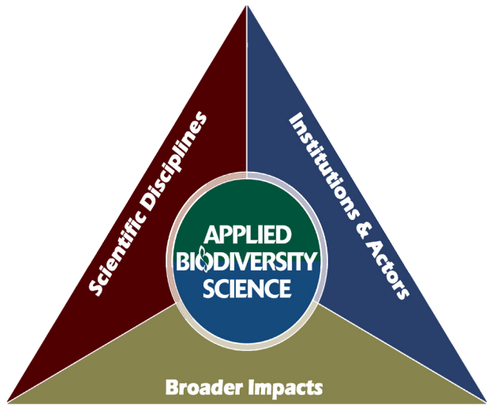
Credit: Thomas E. Lacher, Jr.



Since 2007, the Applied Biodiversity Science at Texas A&M has been one of the world's premier multi-disciplinary graduate education and curriculum programs. The ABS Triangle featured above represents the three pillars that support the programs vision:

1) Integrated education and curriculum in the biophysical and social sciences.

2) Cross-disciplinary research and collaboration with conservation institutions and actors.

3) Valuing and applying multiple disciplines to conservation science and practice.

These pillars provide guidance to students, faculty, and collaborators conducting research around the world related to the Applied Biodiversity Science program's two broad themes: a) ecological functions and biodiversity and b) communities and governance. Each article in this year's issue is representative of the ABS pillars and themes, showcasing how broader perspective leads to innovative and meaningful academic research and on-the-ground practices.

Kenneth E Wallen

Ecological Functions and Biodiversity

What local and historical processes determine presence and distribution of biodiversity? How are these altered humans? These are but a few of the ecology-focused questions ABS scholars and other conservationists around the globe are asking in relation to conventional conservation issues.

In her article, "A century of conservation genetics: a comparative study on the African Lion", Ph.D. candidate Caitlin Curry presents her innovative study examining the impact human activity has had on the genetic diversity of the African lion, *Panthera leo*, and the subspecies *Panthera leo melanchaita*. Rather than a conventional genetic comparison, her study is estimating population size based on genetic diversity found within the population,

facilitating the ability for conservation decisions to be made based on the population's genetic health.

The interaction between a species and local communities can be difficult to manage. ABS associate, Erin Buchholtz's article "Theives in the night: elephant crop-raiding in Botswana", introduces us to her study tracking elephant movement patterns, which can inform farmer's decision-making and improve the relationship between elephants and locals in rural Botswana

Communities and Governance

How do political, economic, and historical phenomena influence conservation? How do institutional arrangements affect conservation efforts? These are influential questions whose answers can shape conservation practices, policies, and outcomes. ABS associate and Ph.D. candidate, Kyle Clifton, addresses some of these questions in relation to the effectiveness of private nature reserve partnership programs in the Greater Kruger in "Partner, perception, and poaching".

In "Oil, gas, wildlife, and communities", ABS professor, Dr. Thomas Lacher, and Dr. Patrick Byakagaba from Makerere University outline institutional capactiy-building and education efforts in Uganda to mitigate conflict and threats to biodiversity and communities.

Lauren Redmore, an ABS associate working in rural Botswana, examines the issue of the government's development subsidies and how these direct subsidies from, while effective at providing temporary relief, do not necessarily provide meaningful, long-lasting achievements of human development.

PARTNERSHIP

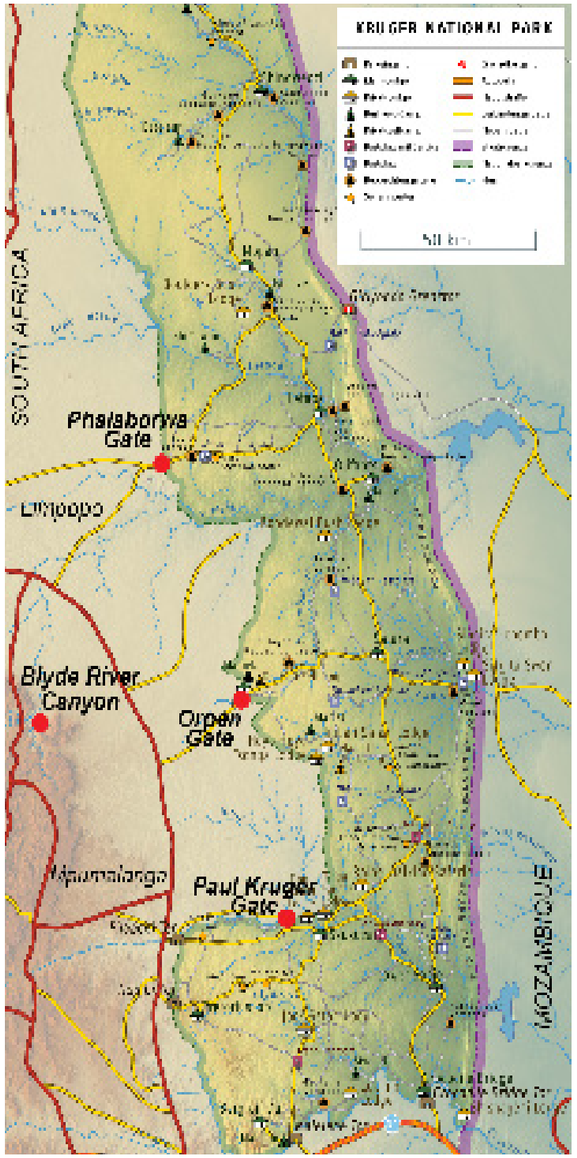
PERCEPTION

POACHING

KYLE L. CLIFTON

Fifteen of the past thirty months have been spent at my field site in the Kruger to Canyons Biosphere, South Africa. I lived in a small house on the boundary between the Limpopo and Mpumalanga provinces, with the Kruger National Park (KNP) twenty minutes to the east and the Blyde River Canyon twenty minutes to the west. The Kruger to Canyons Biosphere (K2C) is a 4.8 million hectare region designated by UNESCO's Man and the Biosphere Programme as being of high economic development and conservation importance. The aim of the Biosphere programme is to establish a scientific basis for the improvement of relationships between people and their environments.

The eastern portion of the K2C encompasses a section of the continent's flagship national park, Kruger National Park, from just north of the Phalaborwa Gate to the Paul Kruger Gate in the south. KNP is iconic; a world-renowned wildlife reserve roughly the size of New Jersey. It borders Zimbabwe to the north and forms a ~360km border with Mozambique to the east. To the west and south of the Kruger is a patchwork of private, provincial, and community owned protected areas managed for conservation. This network of protected spaces is collectively known as the Greater Kruger. The western portion of the K2C Biosphere includes the Blyde River Canyon, which is one of the largest canyons in the world and is also impressively biodiverse. In between the Kruger and the Canyon are the network of protected spaces, mining operations, and over 1.6 million people living in relatively high-density rural communities.



As much as the K2C is an impressive combination of geology, flora, and fauna, it also encapsulates a confluence of historical and current human conflict and challenges. While there was historically settlement in the region, forced relocations under the Apartheid government's homeland policies, as well as displacement during the creation of protected areas (e.g. national parks), caused the human population to both concentrate and grow. And though eco-tourism and mining in the areas provides some employment, there are few industry sectors to provide significant employment to support the population. And as is the case in protected area management around the world, these human dimensions have the capacity to undermine conservation activities.

The Greater Kruger area has long been renowned for ecotourism, but more recently the world is turning its eyes to the region as the epicentre of the 'War on Poaching'. In response to a rapid rise in rhino poaching, protected areas in the Greater Kruger have turned to militaristic tactics to curb rhino population declines. While this militaristic response may be seen as a stop-gap solution to the ultimate resolution of eliminating demand for wildlife products, it is still critical to understand the effects these tactics (namely, 'Green Militarization') and rhetoric have on the communities surrounding protected areas. That is, it is important to identify potentially unintended consequences or second-order problems that may ultimately further threaten the integrity of protected areas and species within them.

The aim of my study is to determine the effectiveness of private nature reserve partnership programs at addressing development priorities in communities and alleviating conflict between private reserves and nearby communities related to development and wildlife conservation. Partnerships are transboundary management programs between private reserves and nearby communities. They are activities initiated or sponsored by the private reservte that act to build constituency between the reserve and community. They include programs such as employment in the reserve, education programs held within the reserve or community, or financing infrastructure development in communities. Rhino poaching is most topical internationally, but I am also interested in occurrences of other types of conflict such as community demonstrations and complaints against the reserve, or wildlife damaging community property or killing livestock.

White rhinos with poached horns in rehabilitation at the Hoedspruit Endangered Species Center in the K2C and warning signs to poachers dot the roadsides and fence lines throughout the area. (credits: Kyle Clifton)

I conducted semi-structured interviews with stakeholders from private nature reserves and members from three case-study communities, each of which was adjacent to a different private reserve. I spoke with reserve stakeholders about (a) community partnership programs with which their respective lodge or reserve was engaged, (b) deterrents to initiating or engaging in these programs, and (c) their perceptions of the degree of conflict with communities and of the efficacy of these programs to address development goals or alleviate conflict. The general topics of the study—conflict with communities, the efficacy of development programs, and rhino poaching—are all sensitive subject matter for the reserves. Information regarding anti-poaching initiatives in particular is held very close to the chest. Detection, response, and intelligence operations are largely carried out as covertly as possible. Because of this, it was crucial for me to spend time in the area to meet at least once with key stakeholders. This helped stakeholders to understand the aims and desired outcomes of my study and to establish a relationship to build trust.

Interviews with community members were conducted with the aid of an interpreter, Lydia Mashabane, when necessary. Lydia is affiliated with a local organization called Plough Back to the Communities. They collaborate with the University of the Witwatersrand and local tribal authorities in assisting researchers working in communities in the area. The motive of their work is to provide research findings back to the communities to facilitate interventions that contribute to the improvement of the standard of living of communities [ploughback.org]. Linking with Plough Back to the Communities facilitated my community entry and helped to establish trust with community leaders, and it will also assist in the crucial final step of providing findings back to the communities within which I collected data.

While there, I lived at the University of the Witwatersrand Rural Facility (WRF). This is a large property that offers accommodations for short-term, long-term, and permanent researchers, students, or tourists. WRF provided an environment that allowed me to mingle with other researchers studying a variety of topics—from HIV intervention, to the economics of natural resource use, to witchcraft beliefs in local cultures. I was able to link with professors there to receive guidance and feedback on the design and implementation of my project. I also collaborated with and was aided by researchers at the South African Wildlife College. Affiliation with known, South African institutions helped to validate me as a researcher and will help in the future to disseminate findings to both groups of stakeholders, and add my work to the broad body of knowledge and research on the area.

Article title images: White rhino and the Blyde River Canyon in the K2C. Above: a community member showing off the mat she just completed. Left: Lydia Mashabane and the author. (credits: Kyle Clifton)

Results of my study will be provided to participating reserve wardens and executive committees, as well as Tribal authorities and Community Development Forums of participating communities. It is my goal to provide communities with relevant information to support effective communication with adjacent reserves, as well as to aid reserves in tailoring their partnerships with communities to improve relationships, reduce conflict, and achieve conservation goals.

Collaboration with local actors and institutions enabled my fieldwork by facilitating access and encouraging trust. But, more fundamentally, it instilled value in my project by shaping its design to ensure it was addressing a needed knowledge gap and by integrating it into the broader body of work in the region. The merit of the connections and collaborations I mentioned here, as well as others I have been able to make, is one of the biggest takeaways of my time in South Africa. While I came to study the effects of partnerships between reserves and communities, I quickly found how much my study itself was affected by partnerships.

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Thieves in the Night

Elephant crop-raiding in Botswana

You are asleep, lying in your bed.

All of a sudden your dog starts barking. You wake up to hear the sounds of an intruder in your house. The electricity is off so you can't see anything, but he sounds massive. You know that there have been armed, dangerous thieves roaming your neighborhood recently; it sounds like one of them has chosen your property to loot tonight. You must decide whether to risk facing the intruder or hope he leaves on his own.

ERIN K. BUCHHOLTZ

This is a frequent occurrence for farmers living in the Okavango Panhandle of northern Botswana. It isn't human robbers they are tormented by, but the 5-ton elephants who raid their crops at night. Although these mega-herbivores lack the malicious intent of thieves, they nonetheless cause serious damage when they come across fields full of delicious crops. Studies across Africa have focused on where, when, and why elephants raid farmers' fields, with hypotheses spanning from opportunistic feeding, to learned raiding behavior, to nutrition-driven foraging.

Likely, there is not a single answer as to why elephants eat crops and cause damage, but instead a complex interplay of causes and circumstances. Climate and weather, environmental variation, history and memory, social behaviors, vegetation patterns policy, development trends, population change; all of these play some role in the social-ecological system. Research is crucial for teasing out the relationship between elephant behaviors and their interactions with humans. For my dissertation research, I am focusing on spatial and temporal patterns of elephant movement and human-elephant conflict. I am taking advantage of technology such as GPS collars, GIS modeling, and applications of circuit theory to better understand and predict where and when elephants move through the landscape. To complement those methods, I have also worked with farmers through the growing season to collect data on crop raiding mitigation and damage, and will be conducting interviews to gather local ecological knowledge of elephant behavior.

Elephants are having a particularly significant effect on farmers' livelihoods in my study region of northwestern Botswana. This area is characterized by subsistence farming, where

the cereal crops which are harvested and milled by hand represent a family's primary sustenance for the year. Crop planting and harvesting takes place during the end of the dry season to take advantage of the following rainy season. Once the rains have stopped, crops have ripened and are ready to harvest and dry. However, during the final rains and into the harvest season, elephants begin to move from their more remote ranges in the bush to closer to the villages. The villages and their associated fields are located near to the only permanent water source in the region, the Okavango River Delta. As the dry season progresses and elephants come to access the water and vegetation along the Okavango, interactions with people –and therefore the potential for conflict– increase.

For the 8 villages along the Okavango that I am studying, over 250 elephant crop-raiding incidents were reported for the 2016 growing season. These incidents range from a single bull elephant walking through the field and crushing plants underfoot, to entire breeding herds which broke through the fence on side of the field and ate their way through the crops until they exited through the fence on the opposite site. Throughout the growing season I was able to collect information on when elephants raided, which fields were affected, what crops were grown, how farmers protected their fields, and if they used any active mitigation measures. I hope that through analyzing these data I will be able to identify any patterns in when and where raids occur, and which mitigation techniques are proving most effective. This information can then be used by the Department of Wildlife and National Parks (DWNP) in order to allocate conflict-response resources effectively, and create and improve management plans.

It can be used by the local organizations as well as governmental initiatives which aim to improve farming practices and reducing conflict. It will also provide feedback to farmers, who have little opportunity to see how their experience fits in to a larger picture. Later this year, I will be meeting with each village to share my findings, including whether there are certain mitigation techniques that are more effective than others and therefore should be prioritized for those with limited resources.

Elephants can raze an entire field during the night. The first time I attended a field that had been completely destroyed by elephants, hardly any of the millet (a tall, staple cereal crop) was left. Stalks were bent and some half-chewed heads of millet had fallen into the sandy soil from the elephants' mouths as they ate. It was like coming into a house where robbers had trashed every room, leaving behind a chaotic mess of of debris and destruction. The destruction can be bleak and disheartening, but it is my hope that with applied research, innovative approaches, and cooperation and compromise, a system is possible where elephants and humans can coexist.

Right: community officers meet with farmers in their fields to assess damage caused to crops by elephants, in the western Okavango Panhandle of Botswana (credits: Erin K. Buchholtz). Previous: Black and white elephant images from regional camera traps (credits: Rocío Pozo).

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A Century of Conservation Genetics

Comparative study on the African Lion

CAITLIN CURRY

Fondly referred to as the "***King of the Jungle***," the African lion is one of the world's most iconic species, of not only Africa but all things wild.

The lion's majestic nature makes it a species held in high regard by many people; however, research and conservation efforts associated with the species are greatly lacking. As the human population in Africa drastically increases, nearly quadrupling over the last 50 years (CIESEN 2005), wildlife has had to adapt to a changing landscape.

Over the past century, lion mortality across its range has been primarily human-related (IUCN 2006a,b). The rise in the human population in and around lion habitat has caused habitat destruction, land conversion and a reduction of the lion prey-base, creating an increase in human-carnivore conflict. While there is no debating that the lion's range has shrunk as a result of human-related changes to the African landscape, the actual impact to the population is not really known.

In July of 2015, Cecil, a regionally famous radio-collared lion from Zimbabwe's Hwange National Park, was shot under suspicious circumstances by an American trophy hunter. The incident quickly received global media coverage generating international interest around the African lion. For a few months in 2015, the public's outcries for the future of the lion were leading media stories.

A petition for the U. S. Fish and Wildlife Service

Previous: Lion skulls at the American Museum of Natural History in New York City, New York (credit: Caitlin Curry). Bottom right: Dr. Paula White darting a female lion in Zambia. Above and left: Male African lions of various ages.

(USFWS) to list the African lion under the Endangered Species Act (ESA) had been in circulation since 2011 (IFAW, 2011) and the recent upswing in media coverage on the species brought about more petitions to bring a decision to action.

On January 22, 2016, the USFWS made a ruling to list the African lion as two subspecies under the ESA, *Panthera leo leo* and *Panthera leo melanchaita* (USFWS 2016).

Subspecies	Population	Listing
Panthera leo leo	Central Western & Central	Endangered
Panthera leo melanchaita	Eastern & Southern	Threatened

This decision was based on what they claim to be the "best available science". However, the current "best available science" may not be showing us the whole picture.

Up until now, the fate of the African lion population has been determined by overall population decline. However, population declines of the African lion are based off "guesstimates" (Nowell and Jackson 1996) of a historical number (Myers 1975) compared to estimates of present day populations (Bauer et al 2015), which vary widely in themselves.

A number of abundance and distribution studies of the African lion have been performed through the use of interviews (Bauer & Van Der Merwe, 2004), spoor counts (Midlane et al 2014), call-ups (Ferreira & Funston 2010; Everatt, Andreden & Somers 2014; Henschel et al 2014), and camera traps (Ferreira & Funston 2010). However, there is no consistency of methodology across regions. And, while genetic studies have been done, they have been primarily phylogenetic in nature with little to no focus on population structure (Antunes et al 2008; Bartnett et al 2006a; Bartnett et al 2006b; Bertola et al 2011; Dubach et al 2013;) or restricted to a particular region (Lyke et al 2013; Miller et al 2014; Spong et al 2002; Tende et al 2014).

My study, being conducted at the Texas A&M College of Veterinary Medicine & Biomedical Sciences under the supervision of Dr. James Derr, is taking an innovative approach to African lion conservation. Rather than comparing finite population "guesstimates", this study is estimating population size based on genetic diversity found within the population, allowing conclusions to be drawn based on the lion population's genetic health.

Using state-of-the-art genetic biotechnology, the study will uncover information necessary to document accurate lion population numbers through genetic diversity. Genetic diversity is directly related to a species' ability to adapt, survive, and thrive within its environment. A loss in diversity is detrimental to the health of the overall population and its long-term survival because it decreases its potential to adjust to an ever-changing environment. The current lack of knowledge about the genetic history within the wild lion population makes it difficult to predict how losses in the genetic diversity might negatively impact its overall health. With the use of genetic biotechnology, genetic information can be accessed from long-dead individuals preserved in museums around the world and their contemporary counterparts through the power of isolating genetic material, or DNA.

Turn of the century naturalists, hunters and explorers have made it possible for us to access historical genetic information by supplying museums and private collections around the world with hundreds of lions from their travels. Tissue, bone, and hide samples are being collected for this study from these collections in the United States, Europe, and Africa. Currently our historical collection consists of 130 specimens dating between the 1880's-1930's and spanning locations where lions still exist, like South Africa, Zimbabwe and Kenya, as well as locations where lions haven't been seen in years, such as French

Equatorial Africa (i.e. Gabon, where the last confirmed sighting was in 1995). Using data from these historical specimens, we will be able to create a baseline for the genetic health of the lion and track changes in genetic diversity over the past century.

The contemporary lion collection consists of modern African lion DNA samples and appropriate data available from previous studies (Antunes et al 2008; Bertola et al 2015; Dubach et al 2005; Driscoll et al 2002; Lyke et al 2013; Miller et al 2014; Morandin et al 2014; Spong et al 2002; Tende et al 2014). Working in collaboration with Dr. Paula White and the Zambia Lion Project, we have already completed mitochondrial analysis of 165 lions from five main areas in Zambia (Curry et al 2015). This sub-study uncovered genetic variation within the African lion population which had never previously been seen. Coupled with high levels of genetic diversity, this finding suggests that Zambia may serve as a bridge connecting populations in southern Africa to eastern Africa, supporting earlier hypotheses that this region may represent the evolutionary cradle for the species.

Current and historic population sizes across the species' range can be determined by looking at the differences in the DNA. And, by tracking changes in genetic diversity over time through the combination of DNA from contemporary lion populations and lion populations that existed over 100 years ago, we can identify the existing wild lion populations that are most at risk and make recommendations to guide management actions accordingly to safeguard their future genetic health.

Ultimately, this project has the ability to set the record straight amongst the emotional cries about the downfall and genetic vulnerability of the African lion. Science is the cornerstone of wildlife management, and this research could provide much needed insight into an issue where feelings often trump fact.

Acknowledgements:

I would like to thank the American Museum of Natural History in New York City, New York for allowing Dr. Derr and I to come to the Department of Mammalogy to collect historical specimens. I would also like to thank the Field Museum of Natural History in Chicago and the Natural History Museum of Los Angele County for providing us with historical specimens. A special thank you to the African Lion Working Group and its members for their support and welcoming me as a member of their organization. Finally, I would like to thank Dallas Safari Club, Safari Club International, Houston Safari Club, Explorer's Club Exploration Fund, the Texas A&M College of Veterinary Medicine Trainee Grant program, the Boore Family Foundation and everyone who contributed to the Experiment.com Cat Challenge crowdfunding campaign for their financial support.

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Top: Sampling lion skulls at the American Museum of Natural History in New York City, New York. Middle: Taking measurements of a modern lion skull from Zimbabwe. Bottom: Using a cryogenic mill to process bone for DNA extraction (credits: Caitlin Curry).

Credits: Caitlin Curry

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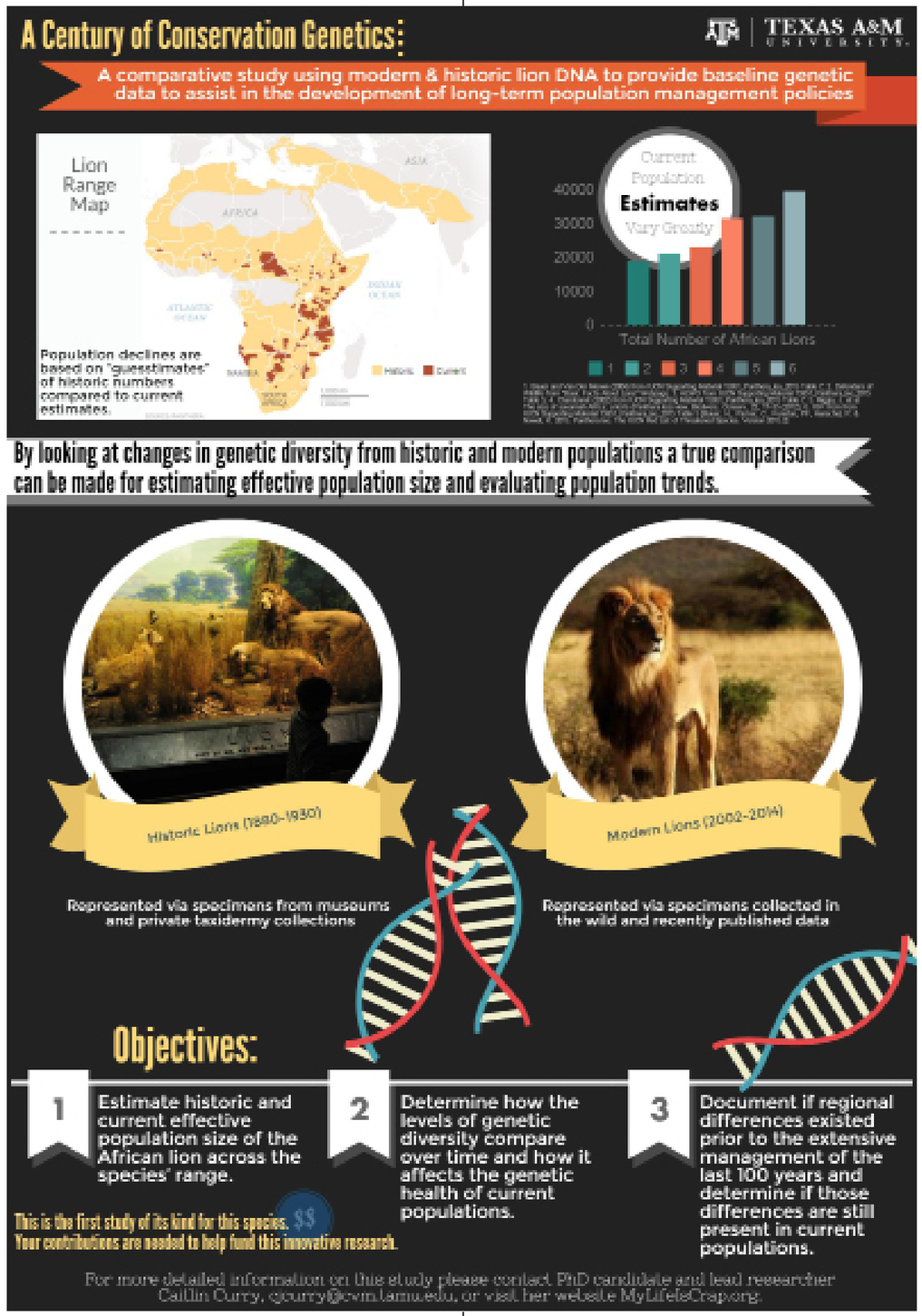

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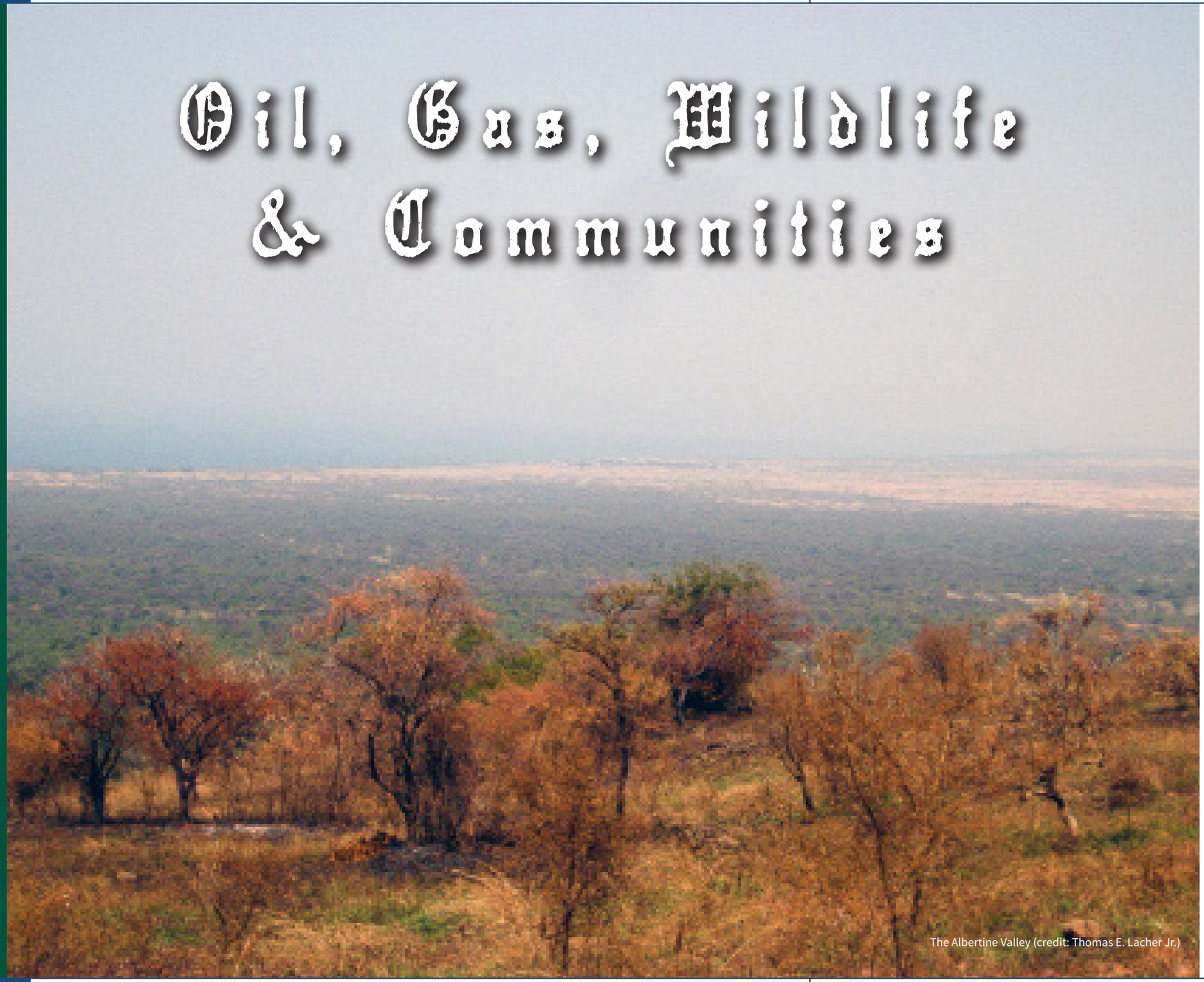
Oil, Gas, Wildlife & Communities



The Albertine Valley (credit: Thomas E. Lacher Jr.)

Capacity Building to Mitigate Conflicts in Uganda

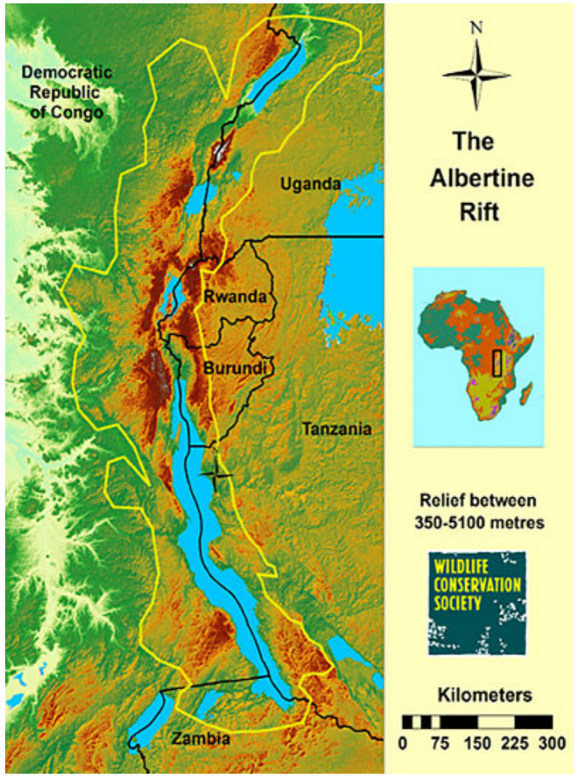
By: Thomas E. Lacher, Jr. & Patrick Byakagaba

At the crest of a dry plateau of scrub forest, the road suddenly reaches the edge of a precipitous drop. From there the road winds down a series of narrow switchbacks. At first glance, the view presents an expanse of hazy, yellowed scrub on the plain below. Further in the distance is a large, pale blue lake, which fades into the horizon. It is a stunning view, the Albertine Rift.

Perhaps more stirring is what we know but do not see; that a mere 200,000 years ago the first members of our species walked that valley. Two hundred thousand years is barely a note in the evolutionary symphony. We are a young species compared to most, but we have come a long way from our hunter-gatherer ancestors. Our demands on the environment have amplified.

Uganda is one of the newest inland oil exploration frontiers in Africa with an estimated 6.5 billion barrels and the larger potential of 8 billion barrels. Most known reserves lie in the Albertine Graben, adjacent to Lake Albert, one of the world's most biodiverse regions.

Several companies have drilled exploratory wells to assess the production potential, including wells inside national parks. In addition, the region is home to a number of traditional peoples and several Community Wildlife Areas, and there is the potential for significant social and cultural impacts in the districts within and adjacent to the primary zones of exploration. Oil and gas is a new opportunity and challenge for Uganda, and there is little current infrastructure to train either petroleum engineers or specialists in the environmental and social impact assessments associated with this new industry. The challenge currently facing Uganda is to develop educational training programs to build capacity within the country to mitigate these threats to biodiversity, natural systems, and local and traditional communities.



Regional map of the Albertine Rift (outlined in yelllow) through six countries (credit: Wildlife Conservation Society).

Biodiversity and Protected Areas in the Uganda Albertine Graben

The Ugandan Rift Valley is located in the extreme northern sector of the Albertine Rift, running from slightly north of Lake Albert south to the border region between Rwanda and the Democratic Republic of Congo. The Ugandan rift region includes two other important lakes in addition to Lake Albert: Lake George and Lake Edward. The massive Lake Victoria sits farther to the east of the Albertine Rift. Much of the country sits on the East African Plateau and habitats vary from savanna to subtropical and tropical forest, with about 50 percent of the country dominated by grasslands and savanna woodlands. Forested ecosystems (about 17% of the land area) are restricted to high elevation zones, like Mount Elgon and the highlands around Kidepo in the east and the mountains of the Albertine Rift in the west, especial along the border with Rwanda and the Democratic Republic of Congo. Due to its varied topography and the tendency for the western region of Uganda to be more mesic, the Albertine Rift is particularly rich in biodiversity.

Both international and national NGOs consistently highlight the exceptional biodiversity in the region around the Rift Valley. It is designated an Important Bird Area by BirdLife International and a biodiversity hotspot by Conservation International. There are many species of both endemic and threatened vertebrates and plants throughout the Albertine Rift, and the region contains more endemic mammals, birds and amphibians than any other site in the continent. The complex of lakes in Uganda harbor one of the largest known assemblages of freshwater fish. The Wildlife Conservation Society estimates the Albertine Rift to contain 39 percent of Africa's mammal species, 52 percent of its bird species, and 19 percent of its amphibian species, along with 14 percent of the plant and reptile species. The 2013 IUCN Red List Assessment lists 183 threatened species for Uganda, including 25 mammals, 22 birds, and 61 fish species.

The USAID report "Uganda Biodiversity and Tropical Forest Assessment" published in 2014 presents an overview of the status of biodiversity in Uganda, and the report emphasizes the critical importance of conservation in the Rift Valley. In good news, the elephant population in Uganda has recovered from a low of less than 1,000 in the 1970s to approximately 5,000, as recently reported as part of the Great Elephant Census funded by former Microsoft executive Paul Allen. The government of Uganda sees value in their wildlife and ecosystems, and there are increasing efforts to maintain and enhance this heritage.

Protected Areas in the oil-rich region include National Parks, Wildlife Reserves, Forest Reserves and Community Wildlife Reserves. The Uganda Wildlife Authority (UWA) is responsible for managing the protected areas of Uganda together with the National Forest Authority. The total network consists 712 units covering 16% of the country, and includes 10 National Parks, 12 Wildlife Reserves, seven Wildlife Sanctuaries, 12 Ramsar sites and five Community Wildlife Management Areas (http://www.protectedplanet.net/country/UG). There are 506 central forest reserves under the National Forestry Authority. The total protected area of Uganda is about 2.2 million hectares and approximately 5000 ha of protected land is under local governments as local forest reserves. UWA reports that Kibale National Park in the Albertine region harbors 13 species of primates in only 760 km^2, including chimpanzees, and the Bwindi Impenetrable National Park contains large populations of chimps and half of the world's population of mountain gorillas. Much of the area under exploration is within the spectacular Murchison Falls Conservation Area, sensitive for biodiversity conservation and a popular tourist destination with many safari lodges, and this presents

Uganda Kob herd on degraded land (credit: Patrick Byakagaba); Cape buffalo (below); Defassa Waterbuck (right) (credit: Thomas E. Lacher Jr.)

the most urgent short-term threat. Queen Elizabeth National Park, also within the exploration region, is the most visited national park in Uganda. The Murchison Falls – Albert Delta Wetland System is a Ramsar Wetland of International Importance and the entire Albertine Graben is a foundation for a growing tourism industry that contributes $650 million a year to the national economy. A fear is that this economic potential, that will extend beyond the period of oil extraction, could be severely impacted should the region become excessively degraded by extensive oil and gas development.

Social, Economic, and Cultural diversity in the Albertine Garben

The Albertine region is one of the most ethnically diverse regions in Uganda. The area where commercially viable oil deposits have been confirmed (Hoima and Buliisa district) is predominantly occupied by indigenous Banyoro and Bagungu, and immigrant communities from neighboring regions such as the Alur, Okebo, Lugbara, Bakiga, and Banyarwanda. The Banyoro are an ethnic group from the defunct Bunyoro-Kitara Empire that used to extend up to some parts of current Democratic Republic of the Congo, northern Tanzania, and eastern, central and western parts of Uganda by the 15th century (Uzoigwe, 1969). This empire has over the years been reduced to only a few small districts in mid-western Uganda, which include Hoima, Masindi, Kibale, Buliisa and Kiryandongo, to form the present day Bunyoro-Kitara kingdom. The Bunyoro-Kitara Empire was reduced to the present day size by the arrival of the British colonial administrators who fought and deposed King Kabalega to the Seychelles Island in the Indian Ocean. He had resisted British colonial administration in his Kingdom and therefore was perceived as a threat in the quest to colonize Uganda. The kingdom was further reduced by annexation from neighboring kingdoms such as Buganda in central Uganda with the support of British military officers. The people were subjugated and ruled by agents and administrators of Britain from neighboring Buganda and since then, local

Murchison Falls on the Nile (credit: Thomas E. Lacher Jr.)

communities have not overcome the trauma and they perceive themselves as marginalized compared to the rest of Uganda.

Oil deposits have been confirmed in Hoima and Buliisa districts which are dominated by Banyoro and Bagungu respectively. Bagungu are a sub-ethnic group of the Banyoro with a distinct dialect of the Runyoro language called Lugungu. They pay allegiance to the Omukama (King) and traditionally provided the security of the boundaries of the Bunyoro-Kitara kingdom from intruders who would come from the north. Bagungu traditionally are cultivators, fisherfolks and pastoralists. Historically, this is because Buliisa district which is their cradle land has ecosystems that can allow them to practice all these three economic activities. Traditionally they were predominantly fisherfolks and pastoralists but this has over the years changed with the decline of fish stock in Lake Albert and competition for grazing resources, resulting in more cultivation. Many of the Bagungu people have migrated to other neighboring areas such as Hoima and Masindi districts to practice crop farming since arable land is extremely limited in Buliisa district.

Customary private and communal land tenure system is the most predominant traditional land tenure system in the Albertine region. Most inhabitants have not registered their parcels in spite of the fact that Uganda's legal framework provides for registration of such land giving permanent inheritable rights to owners, which renders them susceptible to land grabbers who fraudulently register it as private freehold land at the expense of the livelihoods of local communities (CRED, 2015). Lack of formal registration of the land has been one of the bottlenecks in ensuring fairness when the government has to compensate land owners; this has resulted in government being perceived as unfair to her own people. The land in this region varies in terms of value both at temporal and spatial scales and therefore local communities have traditionally preferred communal ownership to enable all members to have access to diverse livelihood options at all times. This however is changing due to the rise in the value of land. There are more people now preferring private ownership of land in the Albertine region partly because of the artificial demand associated with discovery of oil deposits in the region (CRED, 2014).

The Albertine region is also culturally highly regarded by the ancient Bunyoro-Kitara Kingdom which is currently led by a cultural King with extremely restricted authority, since Uganda is a republic. The statutory laws recognize him as a cultural leader who should never be partisan and cannot have political power beyond promoting the culture and norms of Bunyoro-Kitara kingdom. The region retains some of the hunting areas for the King and burial sites for the royal family that date back to over five generations as well as sacred sites for local communities. Some of these sites are found in areas currently managed as wildlife conservation areas by the Uganda Wildlife Authority whose doctrine to conservation is of extreme restriction. This is a potential area of conflict between the kingdom, local communities and the Uganda Wildlife Authority which has the statutory mandate to manage all wildlife conservation areas and antiquities in there.

The discovery of oil deposits in this region is a recipe for conflicts over land resources since the oil and gas industry requires heavy infrastructural development and creates an impression of a bright future for the economy. Unfortunately, land rights are not well defined and secured. There are already reports that individuals who are wealthy and politically connected have started illegally acquiring communal land through unscrupulous

means to be able to harness economic benefits envisaged to come with the burgeoning oil industry (CRED, 2014).

The region has had an influx of other ethnic groups from neighboring regions such as the Alur, Banyarwanda, Banyankole, Bakiga, Lugbara, Okebo, Lendu and Baganda, and this has often created tension due to limited livelihood options and the historical injustices that the indigenous Banyoro people have experienced. Arable land is extremely limited in this area and the influx of other ethnic groups has exacerbated the situation. Conflicts over grazing resources between immigrant communities such as the Banyankole and Banyarwanda with indigenous ethinic groups such as the Bagungu of Buliisa are also on the rise and are most likely going to worsen as the value of land increases due to the nascent oil and gas industry (Médard, & Golaz, 2013; Manyak, 2015). The moral fabric and cultural values that were a hallmark for land governance in the region are at a risk of being eroded as the region becomes more cosmopolitan.

The USAID EMOS Project

The United States Agency for International Development (USAID) released a new comprehensive policy on biodiversity in 2014 (USAID 2014), the first such official policy developed by USAID. The document provides guidelines on the integration of biodiversity conservation into USAID funded development activities. A significant component of this document focuses on a new blueprint for integrating biodiversity conservation with what AID defines as "sustainable, resilient development" (Table 1). The policy document is influenced by other international policies and assessments like the Millennium Ecosystem Assessment (Reid et al. 2005) and a growing concern over the maintenance of ecosystem services. The report highlights many challenges relevant to the Texas A&M Applied Biodiversity Sciences Program, including enhancing disciplinary capacity in training people, improving the governance of conservation,

Tools of the Wildlife Officer, cell phone and AK-47 (credit: Thomas E. Lacher Jr.); Team examining potential drill sites (middle); New oil highway (top) (credit: Patrick Byakagaba)

and reaching policy makers and local communities through the effective use of broader impacts.

With the advent of the discovery of oil and gas reserves in Uganda, a number of international corporations have made investments on exploration and refineries, most notably the French company Total E and P (one of the "supermajor oil and gas corporation), the Irish company Tullow, and the Chinese giant CNOOC (China National Offshore Oil Corporation). In response to this expanding investment, USAID solicited proposals for the project Environmental Management for the Oil and Gas Sector (EMOS) in 2013, and Texas A&M was contracted by Tetra Tech as a partner to assist in the enhancement of capacity to address critical training needs for professionals in fields from petroleum engineering to conservation biology. The initial Texas A&M proposal team included ABS faculty Tom Lacher and Amanda Stronza, Fred Boadu from Agricultural Economics, Teri Reed-Rhoads from Petroleum Engineering, Ed Price from the Conflict and Development (ConDev) Program, and Principal Investigator Paul Schwab from Soil and Crop Sciences. The project has received strong support and participation from Leslie Ruyle of ConDev and the former ABS Coordinator. Our role in the project has focused heavily on assessing current capacity among relevant professionals and developing curricula across disciplines that integrate everything from the training of more conservation focused engineers to the development of skills of environmental impact assessment and environmental toxicology among ecologists and conservationists.

The Ugandan Government agency, NEMA (National Environmental Management Authority), has been aware of these deficiencies and released several reports with support from the Government of Norway; these were key in the development of the request to USAID. A focus was on what are referred to as the Environmental Pillar Institutions of Uganda, which include the Ministry of Water and Environment (MWE), the Uganda Wildlife Authority (UWA), the National Forestry Authority (NFA), as well as NEMA. Key to the training was the engagement of key academic institutions in Uganda, led by Makerere University in Kampala, with strong participation from Mbarara University of Science and Technology and Kyambogo University. Other institutions, namely, Nyabyeya Forestry College, the Uganda Wildlife Training Institute–Katwe, and the Uganda Petroleum Institute–Kigumba, are also engaged. The project is funded by USAID through Tetra Tech under the leadership of the Chief of Party Mr. Jones Ruhombe.

The first two years of participation involved meetings in Kampala with a project management team formed in by Makerere University in Uganda, the Oil and Gas Curricula, and Research Committee of Makerere University (OCRC). The OCRC was initially coordinated and chaired by Dr. J.Y.T. Mugisha. Later, Dr. Joseph Oonyu and Dr. John. R.S. Kaboggoza were hired by Tetra Tech in the role of Senior Technical Advisors on Curriculum Development and Management of the Project based at Mekerere. These meetings helped the Texas A&M team to assess capacity and strengths of programs and identify potential weaknesses in relation to the assessment of oil and gas impacts. Based upon this assessment we began to develop MS-level degree programs and modular instructional tools, in collaboration with Ugandan colleagues. A focus of the curricular enhancements has involved the development of transferrable modules covering topics as diverse as general ecology, wildlife toxicology, social and cultural impact assessment, low impact oil exploration, and governance and legal issues.

Components of these modules were presented to faculty and staff from Ugandan universities and the Environmental Pillar Institutions in July of 2015 and January of 2016. Texas A&M faculty Paul Schwab, Teri Reed-Rhodes and Tom Lacher participated, as well as TAMU graduate students Alejandra Maldonado and Christopher Dermody. Nearly twenty Ugandan instructors also participated by presenting materials that they had developed over the two sessions. This provided for a dry run of many of the modules, and these are

Table 1. The USAID Blueprint for Biodiversity Conservation goals and objectives

Vision	To conserve biodiversity for sustainable resilient development
Goals	Conserve biodiversity in priority places
	Integrate biodiversity as an essential component of human development
Objective	Support enabling conditions for biodiversity conservation
	Reduce priority drivers and threats to biodiversity
	Integrate conservation and development for improved biodiversity and development outcomes
	Build partnerships to mobilize resources in support of biodiversity conservation
	Influence key international policies in support of biodiversity conservation
	Apply science, technology, and learning to enhance biodiversity conservation practice

currently being converted into the "Compendium", containing slides and lecture notes. The compendium will form the basis of the instructional modules that can be added as components to either current classes or newly developed disciplines.

We are now beginning perhaps the most exciting phase of the project, initiating a "Professoriate Program" at Texas A&M University. This fall semester (2016), six Ugandan professors will spend the semester on campus taking classes and participating in multiple activities, workshops, and seminars. Two staff members were selected from each of the participating universities of Kyambogo University, Mbarara University of Science and Technology, and Makerere University with one faculty member focusing on Petroleum Engineering (PE) expertise and one focusing on Environment, Life Sciences and Biodiversity (ELSB). The six visiting faculty are Norah Mutekanga (ELSB) and Titus Watmon (PE) from Kyambogo University; Grace Birungi (ELSB) and Theodora Mondo (PE) from Mbarara University of Science and Technology; and Hillary Kasedde (PE) and co-author Patrick Byakagaba (ELSB) from Makerere University. The PE faculty will take two classes in the Department of Petroleum Engineering and one biodiversity related class in Wildlife and Fisheries Sciences or Ecosystem Science and Management, and the ELSB faculty will do the reverse.

The USAID EMOS Project is a 4-year investment and we are entering the final year of funding. This represents a critical time, because it has become far too common for projects funded over the short term to eventually fade and become inactive as interest wanes and sources of support disappear. The investment in developing capacity, providing instructional materials, and initiating faculty exchanges is designed to try to leave sufficient infrastructure in place to train more trainers to confront the potential impacts of an expanding oil and gas industry. We also hope that the interactions among the Ugandan visiting faculty and Texas A&M researchers will result in project and proposal ideas for research through the College of Engineering and the College of Agriculture and Life Sciences. From an ABS perspective, there are urgent needs for research on biodiversity surveys, conservation planning, social and cultural impact assessment and mitigation, and examination of the influence of foreign investment on natural resource governance structures. The Ugandan participating faculty and institutions are eager to development of new research collaborations and engage both TAMU and Ugandan students in these projects. The Professoriate Program can open up both a new geography and new conservation research questions for the ABS Program.

There is oil under the savannas of Murchison Falls National Park, one of the jewels of the Ugandan protected area system, that many people want taken

from the ground. It is a landscape that leaves indelible images. Two in particular are still very much alive in our memory. We can still hear the roar of the Victoria Nile as it plunges through a six-meter gorge before spreading out into a broad flood plain, supporting populations of hippos, Nile crocodiles and elephants. We can also still smell the dry grass supporting populations of Lelwel hartebeest and Uganda kob that literally stretch across the horizon, in numbers impossible to count. We still have memories of the endangered Rothschild's giraffes as they elegantly stroll and later settle for a good meal of twigs of the savanna shrubs, their necks stretched high above the savanna. Only now, in that same vast landscape, there are oil wells tall among the shrubs.

Patrick Byakagaba meeting with the community (above, credit: Patrick Byakagaba). Author, right, with Sadic Waswa (left) and Robert Kityo (center) on field trip during workshop (credit Thomas E. Lacher, Jr.)

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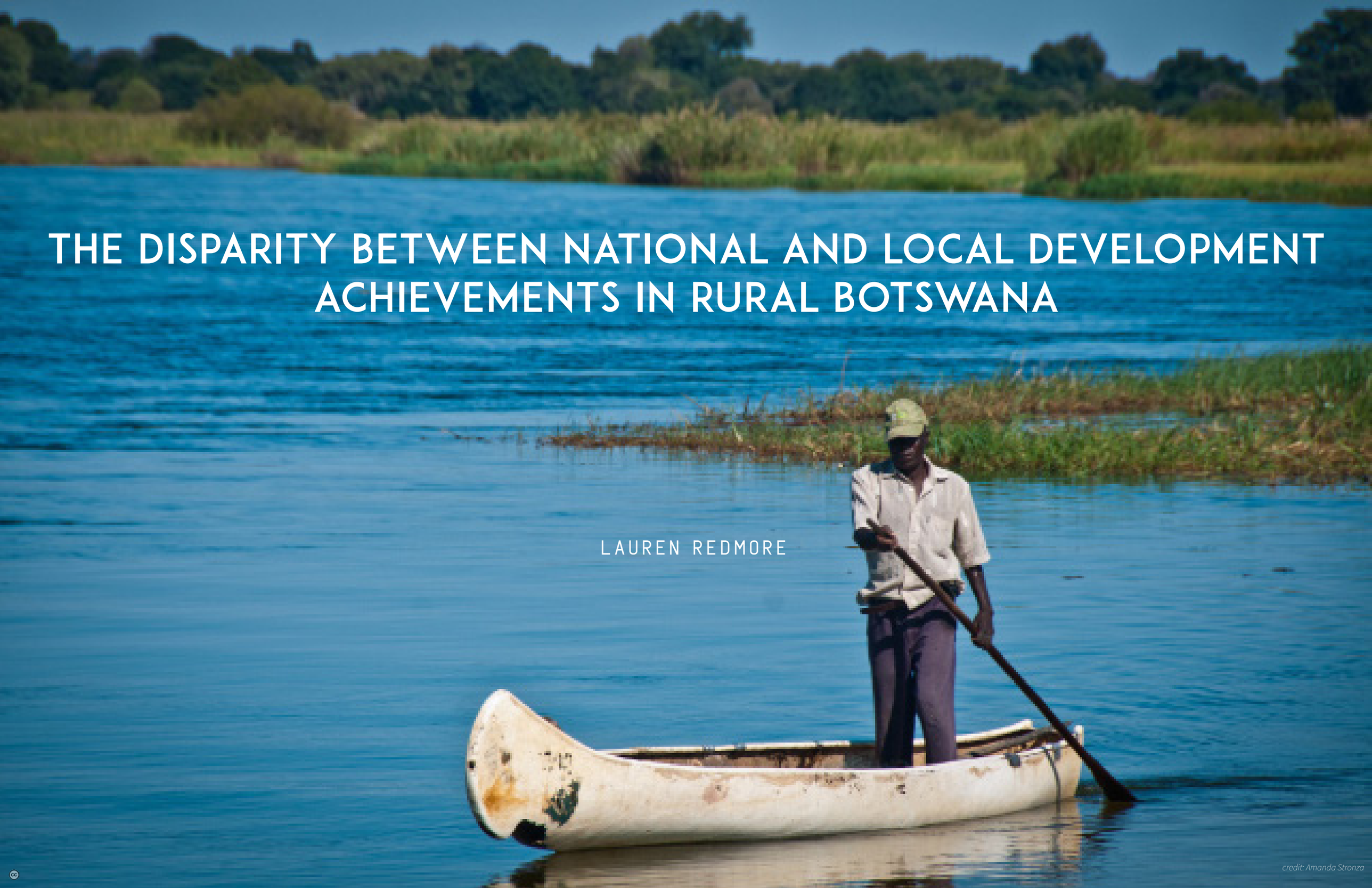
THE DISPARITY BETWEEN NATIONAL AND LOCAL DEVELOPMENT ACHIEVEMENTS IN RURAL BOTSWANA

LAUREN REDMORE



credit: Amanda Stronza

Botswana has earned praise in the development and conservation world for its forward trajectory that stands in stark contrast with much of the rest of Africa. The country has managed to popularize the Okavango as a tourism destination through a rebranding of a seasonal swamp into the enigmatic Delta. Diamond mining, beef export, and tourism have fueled its economic growth, allowing Botswana to emerge as a middle-income country with a highly transparent government and a landscape spotted with exceptional wildlife populations. For visitors accustomed to development challenges prevalent throughout much of Africa, Botswana is an oasis.

Evidence of Botswana's development successes in the well planned, rapidly growing metropolis of Maun seemed to end as quickly as the paved road a few hours north of the city. To get to my field site in the Eastern Panhandle of the Okavango, a ferry transports you across the head of the Delta to a dusty road leading to quiet villages with few shops. Although the rural economy is seemingly at a standstill, the amenities of a pro-development, government-driven discourse have, in many ways, reached the most rural of settlements: water standpipes are scattered around the villages, public latrines are available for use during chief's *kgotla* village meetings, and health clinics are entirely free of cost. However, the Eastern Panhandle is stuck in a development contradiction where large-scale, national development indicators are mismatched at the rural scale.

credit: Lauren Redmore

In my field site many families depend on subsistence agriculture, though the deep infertile sands of the Kalahari hardly provide a sustaining livelihood. In order to bolster agricultural effort, end-of-harvest subsidies are provided to farmers who plow their fields. Potable water is trucked in at no cost when standpipes go dry. Increasing numbers of claimants of wildlife property damage compensation leads to finger pointing at recipients who are largely blamed for not doing enough to protect cattle or farm. Tourism generates significant revenue in secluded tourist camps, but evidently creates few local jobs, and temporary government jobs called *ipelegeng* provide much of the income locally, driving seasonal rural-rural migration into permanent villages.

During my preliminary fieldwork, I have learned that the funneling of money from the multitude of government subsidy programs into Eastern Panhandle settlements is life's blood for many of the rural poor. However, these subsidies remove the possibility for engagement in the workforce as active, creative, self-realizing members of society. Life in the Kalahari is not easy, but direct subsidies are effective at providing temporary relief, not meaningful, long-lasting achievements of human development. Support for small and local economic growth is necessary to move towards more equitable development achievements across the nation and will vastly improve the quality of life for people living in even the most rural of settlements.

credit: Amanda Stronza

credit: Amanda Stronza

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POLICY, DRINKING WATER QUALITY
AND HUMAN HEALTH IN REMOTE ECO-TOURISM

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Ecotourism can support communities and conservation programs. In the remote Amazon forest, sustainable ecotourism and ecolodges can offer local communities economic opportunities while simultaneously protecting the environment from extractive activities. As Krüger states, "the overall potential of ecotourism to generate revenues for conservation is enormous" (2005, p.580) However, human health issues, such as bacterial or viral outbreaks, can undermine local businesses and reputations, with tourism operators potentially incurring penalties and fines in addition to losing customers. Ultimately, human health issues, ecotourism, and conservation are intertwined, with the success of the latter two dependent on practices that limit the impact of the former.

As participants in the ABS Amazon Field School, we examined four remote rainforest ecolodges where despite sincere efforts at sanitation, fecal contamination was found in drinking water supplies (Table 1). We found that human health issues were tied to a complicated web of local, regional, and global policies. To our surprise, the War on Drugs, and the Sustainability movement might be, in a very unexpected way, contributing to making people sick and consequently putting the success of ecotourism at risk.

Over 18 days we were tasked with planning and executing a project related to water and the local socioenvironmental system. Before the field school began, we talked about what sort of scientific tools we could use to understand water issues and decided to build a kit and battery powered laboratory that we could fit into a backpack (Fig. 1). The ABS program and Dr. Georgianne Moore were able to offer us a number of water quality measurement tools, though we had to creatively build a portable bacteriology laboratory. After making modifications, the backpack functioned as a water quality test lab that could run off a portable battery (Figure 1). Working with Krystal Yashe, a microbiology PhD student in the Veterinary Pathobiology Department, we modified a set up used by USDA field agents to test for contamination of milk on extremely rural farms.

We didn't know what we would encounter, so we began building a literature review of heavy metal, sediment, and bacterial contamination and planned to test drinking water sources as well as water sources we had access to, such as rivers, sewage outflow, a lake, aquaculture ponds, mining run-off, trampled shorelines, and other impacted sites. We based our bacterial collection and incubation methods on review of three published methodologies: Standard Methods by the American Public Health Association (Rice et al., 2012), the U.S. Federal guidelines for coliform bacteria testing [40 CFR 141.21(f)], and the 3M Health Care company's methods as validated through the international AFNOR NF mark program ("3M Petrifilm", 2014). These guidelines outline steps such as incubation time and temperature, sample holding times, and describe when not to count a sample as valid.

To our surprise, all the samples of locally purified drinking water at ecotourism lodges, despite efforts to keep it clean, showed contamination with fecal bacteria (Fig. 2, 3, 4). Considering the water was treated in ways that included ozone purification, mechanical filters, and chemical tablets, we were curious as to what was driving this phenomenon. Serious illness caused by poor sanitation could harm a tourism operation, so what was going on? During discussion with lodge managers at

four ecotourism lodges we shared our bacterial culture results and discussed current hygiene measures. We were surprised that in several cases, only soap and water were used for sanitizing containers. We were told by two individuals that it was believed that chlorine bleach was banned in some way. If chlorine was banned, it would explain how contamination was occurring. Bleach is a standard agent for sanitizing containers and is also used to keep water clean. Residual bleach is used in water systems around the world, where a small amount of bleach is present, waiting to kill microbes when the water is inevitably contaminated. On recommendation of a researcher, we confirmed that there were strict rules and a permitting system regarding bleach. This was because bleach is associated with illegal drug manufacture.

Furthermore, we found another deterrent to using bleach; international ecotourism standards use phrasing that was seemingly "anti-chemical." Such phrasing can lead to an over-simplistic rejection of very useful sanitation techniques. Referred to as "chemonoia" or "chemophobia" (Ropeik, 2015), rejection of chemicals can be a feature of Sustainability communities. A prominent accreditation criteria set is The Global Sustainable Tourism Council (GSTC) Criteria. These guidelines require "… a review of each chemical used to identify available alternatives which are more environmentally innocuous" ("Criteria for Hotels", 2012). While this phrasing may sound noble, in the case of sanitation the most effective and well-studied chemicals may be the best choice despite not being classified as the most environmentally innocuous. In this case, any alternative may put safety at risk.

During our travels, we witnessed attitudes among tourists and researchers that could be summarized as "what doesn't kill you makes you stronger" and "the local people are immune to this, foreigners are just weak." There is a body of literature showing that in the developing world, fecal contamination is a serious concern. "Disease-causing

Fig 1. Portable water quality lab, run off a portable battery, while incubating water samples for bacterial testing (credit: CM, AMV).

organisms (pathogens) transmitted via drinking water are predominantly of fecal origin… " and unfortunately "drinking water is a major source of microbial pathogens in developing regions" (Ashbolt, 2004). While many people attribute tourists' upset stomachs to other causes such as lack of sleep or strange food, in fact traveler's diarrhea, called "TD", is actually caused by bacteria. "Bacterial pathogens are the predominant risk [for TD], thought to account for 80%–90% of TD" (Connor, 2015). Most infections causing TD spontaneously clear, but infections by pathogens that cause traveler's diarrhea can be serious, causing complications such as Hemolytic Uremic Syndrome, a type of kidney failure ("E. coli bacteria", 2015)

In 1997 an international outbreak of E. coli 0157 was caused by hotels using an unsafe well. Symptoms included intestinal bleeding and Hemolytic Uremic Syndrome, at least 14 tourists went back to their home countries carrying disease from the well (Peabody et al., 1999). Recently, a tourism resort associated with ecotourism and sustainability in New York suffered a viral outbreak caused by norovirus, a virus spread through fecal contamination. The resort filed to settle the resulting class action lawsuit for $875,000 in 2016. (Platt, 2016). A smaller ecotourism operation could collapse under similar circumstances. Any environmental benefits gained through the ecotourism would cease.

To evaluate direct observations of human health, we observed 10 of our companions during our travels. We also spoke with personnel at the state-of-the-art lodges, where staff had experience with long-term visitors. We met with a lodge manager, a personnel manager, a tour guide and two embedded researchers. Seven out of ten companions became obviously ill. The embedded researchers discussed frequently observed bouts of illness and one praised the antibiotic drug Ciprofloxacin as an important tool for getting people back in the field and working quickly. We were both ill at different times during our trip.

While lodge staff were familiar with illness in longer term guests, the majority of guests had short two or three day stays at lodges as a part of longer regional tours. Because bacterial infection requires an incubation period before illness occurs, it may be that short visits ended before illness began in a way that would be visible to staff. Each lodge manager identified TripAdvisor.com as a major source of reviews and feedback regarding their facility. To our surprise, out of hundreds of TripAdvisor reviews, there were very few mentions of illness. For example, Lodge 4 over had over 350 reviews, with only eight reviews mentioning illness of any sort, several of which pointed blame for illness on factors other than the lodge. Four water quality comments existed, all which discussed purified "good" water being plentifully available. This was at odds with both the knowledge that longer term guests reliably became ill and the water contamination we observed.

In reviewing literature and interviewing locals, we observed several co-occurring factors potentially hindering recognition and treatment of local water contamination. First, a federal laws bans bleach in wilderness areas without difficult permitting and record keeping processes. Second, an anti-chemical and anti-health bias was held by guests and international recommendations whereby chemicals were considered bad or undesirable and being sick was considered a way to strengthen one's immune system. Third, the major source of reviews was largely devoid of any indication that health could be an issue, as apparently the frequently ill long-term guests did not report their illness on TripAdvisor. Fourth, bacterial testing kits were not in use by the lodges, including inexpensive "H2S" color changing bacterial presence/absence indicator tests. Finally, lodge managers appeared to trust their water purification methods without considering the potential for contamination after initial treatment.

As a follow up to our study, we have written up a list of recommended actions and shared our results with a regional accrediting body, an industry leader with influence within the lodge association, individual lodge owners, and researchers working in the region to discuss possible solutions. We are currently working on a shopping list of low cost tests for bacterial contamination that lodges can use, along with recommendations to reduce fecal contamination after purification. In order to enable stakeholders to solve this issue from a legal standpoint, we are helping them locate the relevant law and legislators as well as providing sources about best water quality policies.

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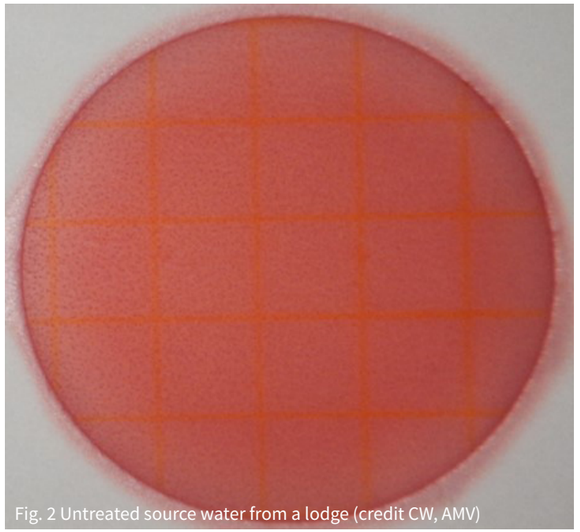


Fig. 2 Untreated source water from a lodge (credit CW, AMV)

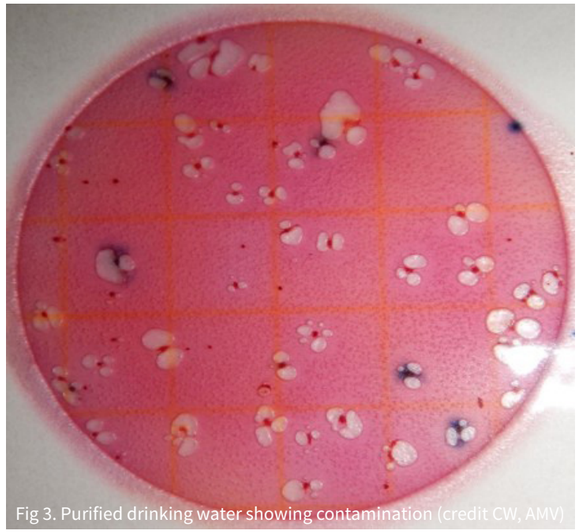


Fig 3. Purified drinking water showing contamination (credit CW, AMV)

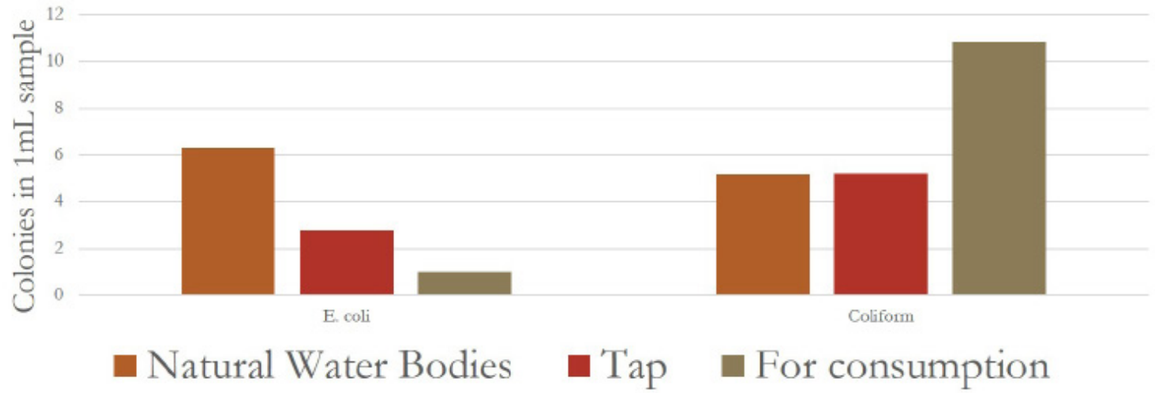
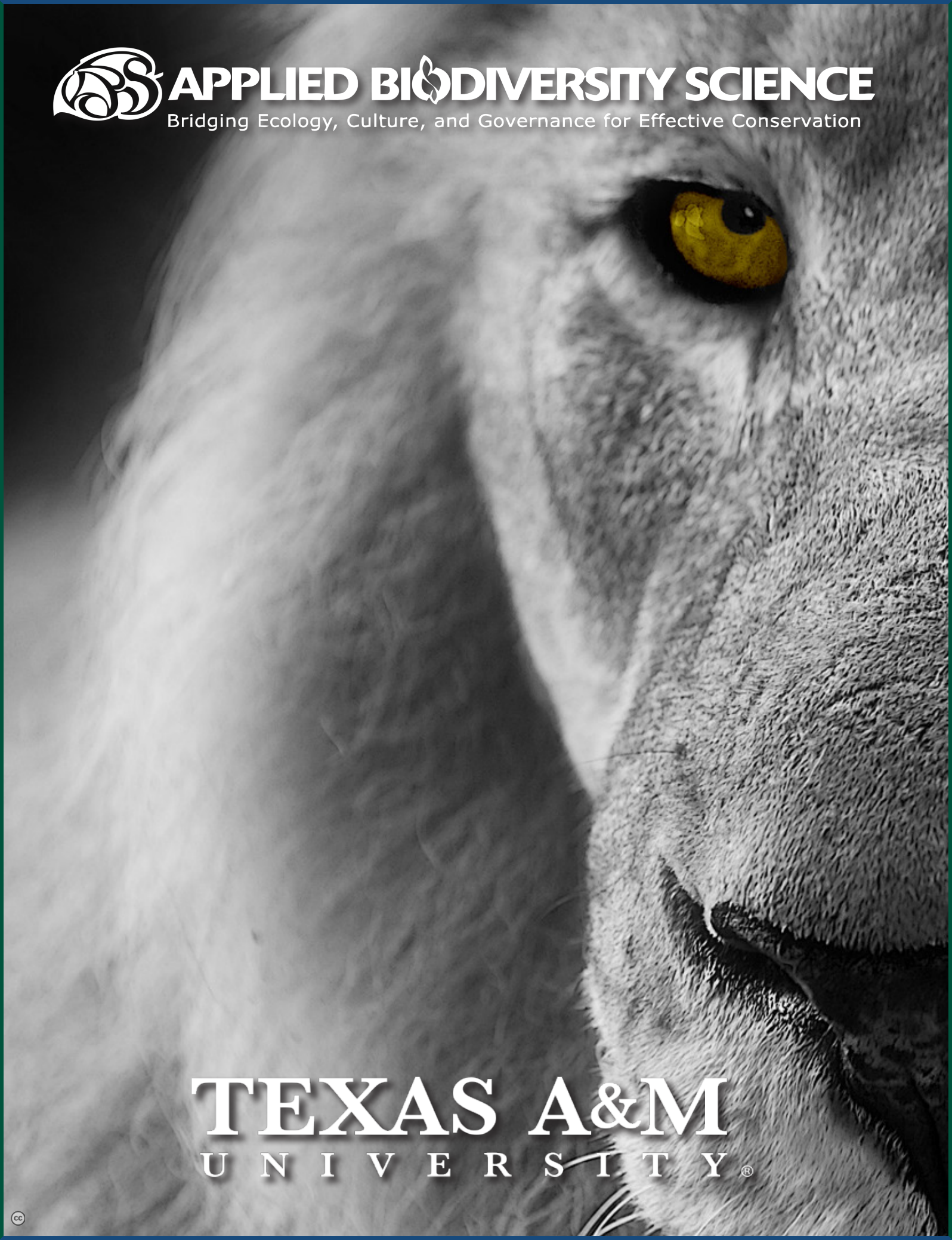


Fig 4. (credit: CM, AMV).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