The Great Zebra and Giraffe Count: The Power and Rewards of Citizen Science

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Executive Summary

Successful conservation in African depends on a number of practical elements being available, 1) good data on wildlife numbers to inform management decisions, 2) public and political support and 3) adequate and sustainable funding. Getting all of these ingredients right is difficult. We explored how the possibility of using a new citizen science model to meet all three needs and thus help transform conservation in Kenya. The individual based ecological Information System—IBEIS--uses the HotSpotter algorithm to differentiate individual zebras based on their unique stripes and giraffes based on their unique snowflakes. Repeated observations enables accurate population estimates through a simple 'sight-resight' method, a form of non-invasive 'mark-recapture'. However, thousands of photographs are required.

To amass such a large number of images, scores of visitors were attracted Nairobi National Park to participate in the first ever world-wide citizen science project using IBEIS. Over 70 volunteers participated. Not only did they pay park fees, they also contributed to the generation of 10,000 photographs of zebras and giraffes over two days. Using IBEIS, we estimated that Nairobi Park had 2,307 ± 366 zebra and 119 ± 48 giraffe in early March 2015 and that the zebra population is stable.

This method is cheap and quick, and generates important information for park management since this population is migratory and could be under heavy poaching threat while outside of the park. Volunteers participating in the project were incredibly enthusiastic. All were rewarded for their contribution with a certificate that illustrated the route their car used, a sample of the zebras they photographed and if previously known where they were first seen and how the algorithms made the match. Clearly, involving the public in conducting research not only generates a new appreciation in zebras and giraffes, both animals that are common and largely ignored. But it also can be a hook for attracting fee paying people who would not otherwise have come.

A second survey of zebras and tests of IBEIS on elephants was conducted in Amboseli National Park with school children, community, local herdsmen, park rangers and tourists. Undertaken by Princeton and Columbia University students as part of an ecology field course, this study revealed local and international interest in participating in citizen science; tourists even hired cameras to participate. Testimonials and interviews revealed that IBEIS could transform science, public awareness, education and management of zebras, giraffes and many endangered species in Africa.

Rationale

As species vanish, governments often invest large amounts of resources to conserve them. This often creates a paradox. While the public is taxed to support these actions, the same public often does not partake of the benefits that government actions create. Often this is because the parks and reserves are far from urban areas and inaccessible to those of modest means. Yet, even Nairobi National Park, which is only 7 km form the center of Nairobi, is underutilized by the Kenyan public. To change this mind set, the Kenya Wildlife Service (KWS) and WildlifeDirect initiated a Wildlife Festival centered around 'World Wildlife Day' that involved a 'Great Zebra and Giraffe Count'. This was designed to be a massive citizen science event that would draw people to Nairobi National Park to help KWS scientists answer two fundamental questions: How many zebras and giraffes are resident in the park and are these populations stable and self-sustaining?

To answer these questions a 'mark-recapture' project was undertaken to estimate overall population size for each species and the number of individuals in age classes using IBEIS (Image Based Ecological Information System). Since zebras and giraffes are distinctively marked and IBEIS uses new, effective and efficient visual recognition algorithms to identify individuals based on distinctive markings—nature's natural barcodes for zebras—no invasive marking of animals was necessary. Instead, members of the public could simply take pictures of zebras and giraffes that the IBEIS team then could compare to pictures of individuals previously identified and archived in a database. Thus the 'mark-recapture' project became one of 'sight-resight'.

Involving the public made the public part of the scientific process and insured that massive numbers of pictures would be taken, thus making the population estimates robust. The public also benefited in many ways. Since taking pictures required looking closely at animals, those taking the pictures were educated and enlightened. Working with scientists also taught participants about the scientific process. And learning about conservation issues associated with these charismatic species empowered them, hopefully making them champions of wildlife and wise environmental decision-makers.

Methods

In the weeks leading up to the Great Counts, members of the IBEIS and KWS teams

drove the roads of Nairobi National Park taking pictures to compile a database of zebras and giraffes and to identify 5 park blocks whose effort to complete varied and could be matched to the amount of time that teams could devote to assisting with the counts. In the run up to the Great Counts, over 1000 zebras and 50 giraffes were identified and were used to create the first National Park image database.

Over two days—march 1st and 2nd 2015--the plan was to distribute volunteers to drive all 5 regions of the park and photograph as many zebras and giraffes as possible. All zebras and giraffes photographed on day 1 would constitute the class of 'sighted' (S1) individuals. On day 2 another round of individual zebras and giraffe would be photographed (S2), some of which would be new individuals while others would be individuals resighted (R) from day 1. The 'Hottspotter' algorithm that finds matches among images would be used to determine which individuals were newly seen during the count, but most importantly, it would be used to identify those that had been resighted on both day 1 and day 2. Armed with values S1, S2 and R, the population sizes of zebras and giraffes could estimated from the Lincoln-Peterson Index:

$$N_{estimate} = S1*S2/R.$$

The 95th percent confidence interval about this population size estimate is:

$$N_{estimate} \pm 1.96 \sqrt{((S1^2 * S2[S2 - R])/R^2)}.$$

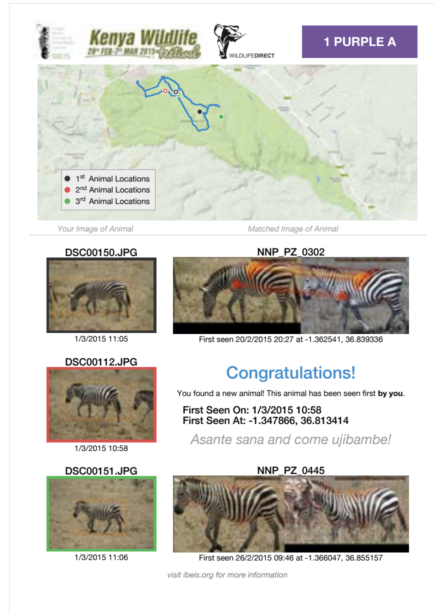
The Lincoln-Peterson Index assumes that during the interval between the first and second counts, no births, deaths or immigration or emigration events occur. Given that the counts were on adjacent days, these assumptions are met. Application of the index also assumes that all animals are equally likely to be captured, or in our case, sighted. Given that different drivers and photographers were likely to have different biases in the way they drove their routes and photographed the zebras they saw, then by the central limit theorem, such differences offset and increase the likelihood that the equal catchability assumption would also be met.

In order to assess the sustainability of the zebra and giraffe populations, each uniquely identified individual was aged and classed as either infant (< 1 year of age), juvenile (> 1 year of age, but < than 3 years of age) or adult (> 3 years of age). Using chi-squared contingency table analyses, the distributions of individuals within each of these three stage classes could then be compared with those of other stable populations such as the Serengeti. Based on previous analyses, stable populations tend to have at least 25% recruits (infants and Juveniles).

Advertising prior to the event (see figure above) led to the registering of many teams. But on the day of the counts (March 1st and 2nd 2015) members of the public entering the park were also recruited to join the count. Over the two days, 31 teams involving 75 volunteer photographers participated in the count.

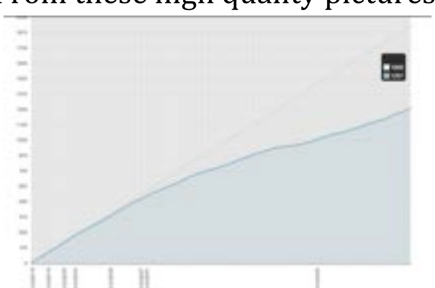
Each team was given basic training on what loop they were to drive and how to take useable photographs; they were instructed to photograph the left side of the animal, preferably capturing most of the flank and if possible some of the face. They were also given a map with the block they were to drive and a GPS tag to be attached to the rear view mirror that would record the route actually driven.

After returning to the registration point after concluding a drive, the information from the GPS tags and images from the SD card from each photographer's camera were copied to IBEIS hard drives. Each volunteer photographer was given a take home 'thank you gift' that showed the route driven, and three of their images, the location on the map where their images were taken and, if in the database, the name and location of where that individual was first sighted. In addition, the 'hotspots' that produced each match were shown and connected to the hotspots on the archived photograph. If the animal was newly identified then the photographer was congratulated on enlarging the database. The figure to the right is an example of one such 'take home gift'.

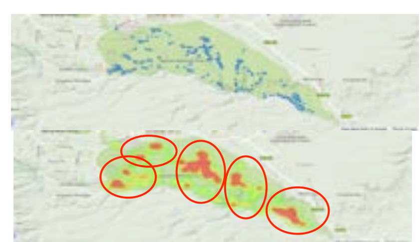


Results of the Nairobi National Park Count

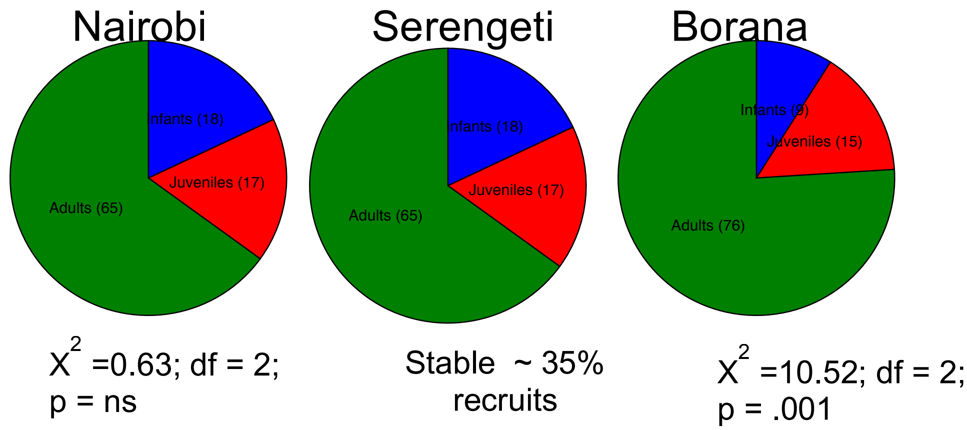
Of the nearly 10,000 images taken, 3610 were of high quality and used in the analysis. From these high quality pictures, 4,546 good images of zebras and 466 good images of giraffes were analyzed. 1,258 unique zebras and 103 unique giraffes were identified, named and aged. Based on the Lincoln-Peterson index, the size of the Nairobi National Park zebra population at the start of March was 2,307 ± 366. As the figure to the left shows, the cumulative number of images was still increasing by the time we finished the count. Thus not surprisingly the estimated population size is much larger than the number of unique individuals identified—in fact almost double.



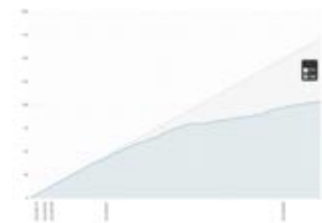
The figure to the right reveals where vehicles stopped to photograph zebras. This bottom figure is a 'heat map' illustrating the intensity of habitat use by zebras based on the intensity of photographic captures. Clearly, all 5 blocks were well sampled.



The figure below shows that 35% of the Nairobi National Park zebra population consists of infants and juveniles. Since the plains zebra population of the Serengeti is stable, we compared the age class distribution of this population to the Nairobi Park distribution. There is no statistical difference between the two populations, suggesting that Nairobi National Park's zebra population is also stable. This contrasts with the age class distributions of plains zebras on the Borana and Ol Pejeta conservancies in central Kenya where lion densities are very high. On these conservancies recruits only comprise 12% of the populations.

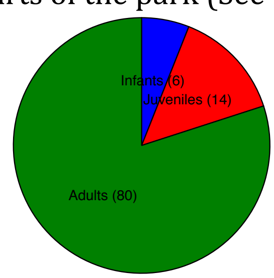


Based on the Lincoln-Peterson index, the size and 95th percentile confidence interval of the Nairobi Park giraffe population at the start of March was 119 ± 48. Unlike zebras, after two days of photographic sampling, the cumulative number of giraffes identified was approaching a plateau suggesting that most of the individuals in the park had been identified (See figure to the right).



The heat map of giraffe image captures shows that they were seen in all 5 blocks, but mostly along the river that bounds the southern edge of the park. This is very different from the intensity of zebra sightings that were mostly in the central and northern parts of the park (See figure to the left).

Adults dominate the age structure of Nairobi Park's giraffe (See figure to the right). They comprise 75% of the population. With no other populations for comparison, we cannot determine whether the population is stable at this time.



Discussion

The 'Great Zebra and Giraffe Count' shows that with the right tools—IBEIS and its 'Hotspotter' algorithms for identifying matches among individuals--involving the public in scientific research can help answer some basic, yet important questions about the size of populations and their demographic health and sustainability. And if in two days the public can provide KWS with population estimates with relatively small confidence intervals in one park, then enlisting the public throughout Kenya to do so in many other parks could be transformative for science and public awareness.

It is important to note that the population size estimate for Nairobi Park is a snap shot at one point in time. But if this exercise were to be repeated across seasons and years, then a more dynamic picture of zebra and giraffe use within the park could be pieced together. Since the location of each uniquely identified zebra was recorded, repeated sampling could identify the extent to which the population is sedentary or migratory and which individuals fall into each class. Even on the 'take home gift' it is easy to see how far individual zebras moved between the volunteer photographer's sightings and the first sightings recorded by a member of the IBEIS team no more than a week earlier. And for those zebras and giraffes that are resident, monthly and seasonal home ranges could also be determined. Armed with this in depth understanding of population movements, sizes and sustainability, KWS would be able to monitor the potential impact of wildlife on human settlements surrounding the park.

As the algorithms embedded within IBEIS are further refined it should become possible to apply them to studying the population and movement dynamics of heavily poached species such as elephants and rhinos. In the second portion of this report some preliminary analyses on elephants is provided.

In addition to the public helping KWS learn about the population size and sustainability of the zebras and giraffes of Nairobi Park, the public itself was transformed by the experience. Many of the volunteers noted that they learned so much about zebras and giraffes. Instead of seeing them as 'wall paper', by stopping and focusing on them through the lens of a camera, the volunteers were able to actually watch them and see them feeding, fighting and mating. The children, in particular, were energized by the experience, asking repeatedly if they could do it again. Since children often change the behavior of adults, engaging Kenya's youth could be a powerful tool for conservation.

Overall, the Great Zebra and Giraffe count created a win-win-win outcome. Not only did this massive citizen science event result in some good science, it did so by engaging the public and enhancing awareness of KWS' mission. And looking forward, involving tour operators working within and adjacent to lands that KWS manages, it could boost Kenya's tourism sector by making science part of the wildlife experience.

Expanding protocols to Amboseli National Park: Estimating zebra population size, testing 'Hotpsotter' on elephants and engaging a range of publics

As was the situation in Nairobi National Park, the estimated numbers of zebras using Amboseli National Park were not known. Thus the first aim of taking IBEIS and its 'Hotspotter' Algorithm to Amboseli National Park was to apply the techniques of image capture and analysis used in the Great Zebra and Giraffe Count at Nairobi Park to Amboseli Park where zebras are less habituated to human activity. If the computer algorithms and sampling strategy could produce estimates of the size of the zebra population under these conditions, it would provide a strong case for KWS to employ them in assessing population sizes in all the parks and public lands that KWS manages.

Second, we wanted to learn if the current version of the Hotspotter algorithms would work on elephants that are less distinctively marked although they have wrinkled skin complexly shaped ears. And third, we wanted to see if it was possible to engage a variety publics and stimulate their interest in aiding scientists studying the population biology of species of interest to KWS. Accordingly, students in the 'Princeton Field Semester in Kenya' and staff from WildlifeDirect visited Amboseli National Park. There they took pictures of elephants and zebras and interviewed members of different publics—KWS officials, community members, tourists, safari drivers, hotel managers as well as students and their teachers.

Methods used in Amboseli National Park

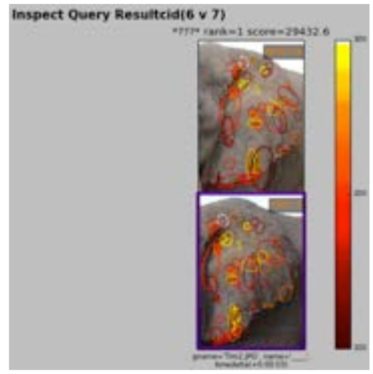
A team of 14 people within three different vehicles drove around a section of the park taking photographs of zebras and elephants. Members of the team gathered photographs over two days. For zebras, they collected 94 useable photos on the first day and 139 photos on the second. In addition, approximately 100 photographs of elephants were taken and Hotspotter was run on different parts of the body to determine which, if any, had sufficient numbers of distinctive features for successfully identifying matches among photographs. Images of faces, flanks and rumps along with ears were taken to see what worked best with the current version of Hotspotter.

Informal interviews were also conducted with several different public groups to assess the potential uses of IBEIS. These included: KWS, Community Rangers and Scouts, NGO's operating in the area, conservancy managers, community leaders, women, teachers, school children, tour operators and tourists.

Results of the Amboseli Project

Amboseli's zebras. From 233 images of unique zebras, the Lincoln-Peterson index yielded a population size estimate of 3276 with a 95% confidence interval of ± 3155. Because only 4 zebras were resighted on day 2 that were first seen on day 1, the confidence interval is very large. Normally 20% of the images taken should be resightings in order to produce small confidence intervals. Since this is a non-habituated population, the only way to increase the total number of useable pictures—thus increasing the number that will be resighting--off road access will be required. And since the students only surveyed about 30% of the park the estimate is a regional estimate only. Since the students visited Amboseli during the dry season, sampling solely within the park was warranted because during the dry season most zebras in the greater ecosystem confine their activity to the park. In order to understand the effect of seasonality on movements and habitat choice, however, surveys will have to be undertaken during the wet seasons and this will require photographing zebras in the surrounding conservancies as well. Overall, this short and limited trial demonstrated that the Hotspotter algorithms worked on zebras not used to being tracked by humans.

Testing the algorithms on elephants. Preliminary analyses of visual features of elephants in the vicinity of Amboseli National Park showed that the software was capable of distinguishing individuals by skin wrinkle patterns. However the Hotspotter algorithms often focused on mud spots or color changes after elephants got wet. In these instances, the hot spots detected were not permanent physical features. The algorithms, however, also detected hotspots—mostly vein patterns--on elephant ear and these more permanent markings enabled successful repeated identification of individuals form different photographs (see figure to the right).



Interviewing the Amboseli publics. Once people saw how effective IBEIS and its Hotspotter algorithms were in identifying individual zebras and elephants, they believed that the system could provide benefits to their constituency. These benefits ranged from saving time and money for researchers studying movements, to reducing the overall number of human/wildlife conflicts by identifying and tracking animals that come in contact with settlements, especially those considered 'problem individuals'. It was noted, however, that limited access to necessary hardware for operating IBEIS and financial constraints of running the software were the major drawbacks at the moment.

Many believed that IBEIS could also provide hands-on learning experiences for rural schoolchildren by increasing their knowledge of conservation as well as by better preparing them for university and subsequent careers in wildlife conservation. Results showed that students were excited about the IBEIS system and teachers believed that the use of image based identification of wildlife could be successfully integrated into the existing curriculum. KWS also felt that IBEIS would also encourage schools to visit the park, a key goal of the Community and Education component of the management plans of Kenya's National Parks.

IBEIS also showed that it has the potential to draw in more tourists by getting people excited about wildlife. Interviews with tourists both online and in person showed support for the idea that tourists would be excited to participate in IBEIS assisted identification research projects. Furthermore, they felt that it would enhance their game viewing experiences. Driver guides, acknowledged that they were best placed to use this software, however, they were less willing to participate on a volunteer basis than were tourists. Hotel managers were willing to implement IBEIS stations in their lodges as soon as the software became 'user friendly'.

Overall, the Amboseli tests reaffirmed the findings from the Great Wildlife Counts at Nairobi National Park. Current algorithms that worked well on zebras and giraffes also could be used to identify less habituated wildlife and elephants based on ear vein patterns. Moreover, interviews with members of various publics confirmed what tourists reported after the Nairobi Park Great Counts—great enthusiasm for helping with science. And if the algorithms for recognizing elephants can be improved and funds can be found for a widespread roll out, new partnerships between KWS scientists and members of various publics could become a powerful tool for conservation.

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