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eBird: Engaging Birders in Science and Conservation

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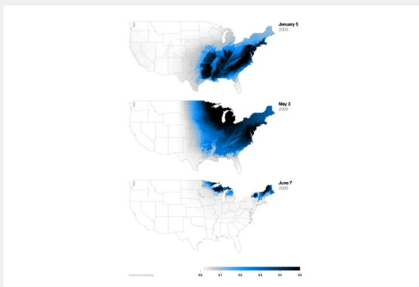

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Identifying a species is a complex task that relies upon a combinatio
Observers must be able to process impressions of shape, size, and
variable conditions. As this process takes place, the observer must
impressions against a list of species most likely to occur at that spe
and constantly recalibrate until the two agree, and the species is co
humans can make this difficult computation of classifying organism
And for birds, tens of thousands of people do this every day for fun.

For more than two hundred years the public has contributed signific
understanding of bird identification, distribution, and abundance [1
tradition, eBird (http://ebird.org/) is a citizen science project that tak
numerous information technologies to engage a global network of
bird observations to a centralized database [2]. Anyone, anywhere,
submit observations of birds via the Internet or through a variety of
These amassed observations provide scientists, researchers, and
with data about bird distribution and abundance across varying spa
All data are free and readily accessible through the Avian Knowledg
eBird data have been used in a wide variety of applications, from hi
importance of public lands in conservation [5] to studies on evolutio
biogeography [7].

eBird is part of the growing field of human computation, which focus
human intelligence to solve computational problems that are beyon
existing artificial intelligence algorithms [8]. Many of these services
include game-based approaches such as the ESP Game, which has
image labels [9]; FoldIt, which attempts to predict the structure of a p
advantage of humans' puzzle solving abilities [10]; Galaxy Zoo, whi

than 200,000 participants to classify more than 100 million galaxies
Sloan Digital Sky Survey [11]; and reCAPTCHA, which provides secu
web while transcribing old print material one word at a time [12]. In t
our experiences in developing the eBird network of volunteers, who
provide an open data resource containing the most current and co
information on bird distribution, migratory pathways, population tre
use.

Know Your Community

eBird uses data collection protocols that match the way birders go
fundamental data gathered with each observation are: species, da
whether all species detected are included on the checklist. Most ob
counts of individuals for each species, and basic information that id
and describes how the count was conducted (start time, duration, a
We chose this relatively simple approach to survey design in order
number of participants, as increasing complexity of protocols in citi
tends to decrease the number of participants in those projects [13]
protocol captures the majority of eBird observations, birders also h
provide additional detailed information for each observation, such
breeding behavior, and additional comments.

A significant aspect of the data that birders contribute to eBird is th
has an exact date and is linked to a point on the map. This provides
eBird data with a variety of covariate data that potentially influence
as weather, climate, habitat, and human population density. This all
community to focus on what it does best: finding, identifying, and co

While we encourage all eBird contributors to conform to the protoc
developed, we also allow users to enter data in a variety of other w
these observations may be of reduced analytical value. For exampl
gather detailed location and temporal specificity, historic data ofte
at the county or even state level. Other counts may be entered that
or that simply report incidental or random observations of birds. Fle
increases initial involvement, and once involved with eBird, we can
toward improved data collection techniques. We have found that by
incentives and training on the eBird web site, we can convert most
observers into higher quality data collectors who use the effort-bas
(see below).

Maximizing Participation

Initial reaction to eBird from the birding community was lukewarm, a
growth in participation. Recognizing this, we modified our developm
on building tools that appeal to, and provide a service for, birders. E
allowed birdwatchers to keep track of their observations, view their
and compare their observations with others, we built upon the esta

birding community. The result was rapid and sustained growth. For
six years, eBird's usage has increased dramatically, with the numbe
submissions to exceed 1.7 million from more than 210 countries in 2

eBird participation generally follows Pareto's Law (the 80/20 law), w
data submitted by a very active subset of "power users". For examp
submitted to eBird have come from the most active 10% of users. U
power users allowed us to develop eBird features focused on these
the belief that this would in turn increase broader participation. Ove
been successful in greatly increasing participation. Having the majo
by committed, repeat users helps maintains high data quality, since
commitment to the project, and an understanding of its best practic
investment in the community. One should not confuse eBird power
birders". While many eBird power users are indeed experts in terms
detecting, and identification, many other birders with more modest
users who may only enter data from their backyard or local area. Th
detect very rare species in their region on the basis of sound alone
proficient with a subset of regularly occurring birds, and they provid
samples of the birdlife in a defined area over time. Moreover, throu
participation they develop a higher level of eBird expertise.

Changing Behavior through Tools and Visu

Once we are able to engage a birder in eBird, we focus on modifyin
checklists entered are more useful for research and conservation.
techniques to encourage higher quality submissions: education ab
making small changes to the way you go birding can improve the va
incentives that reward participants for collecting data following mor

Users receive educational training regarding the scientific reasons
methodologies in eBird, and learn improved data collection techniq
project leaders and volunteers. Even more effective in transforming
incentives in the form of visualizations and data output tools that de
data collection techniques benefit our users on a personal level. W
bar charts (Figure 1) to tackle one of our biggest challenges: encou
from reporting two or three highlight species seen during a day of b
complete checklists of all species seen and heard from a series of r
throughout the day. Bar charts are intuitive data visualizations that
traditionally used to understand the seasonal timing of birds within
finding guides often include these charts to give a visual represent
expected to be present in a region (usually a state). eBird has autor
of bar charts and similar visualizations that depict frequency of occ
birders could understand the seasonal patterns of bird movements
interest. The key is that in order for these visualizations to work bes
submit *complete lists of all species recorded*. Birdwatchers now have a
improve their data collection techniques. Equally important, they no
regularly enter records that help develop these bar charts. We also
tabular outputs (eBird's "Top 100") that give recognition to the user

the most checklists or observed the largest number of species. This important tool helps maintain high levels of participation by allowing engage with each other in competitions to submit more complete cl species. This combination of educational features and data output personal reward are very powerful motivators for generating increa quality.

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Figure 1. eBird frequency bar chart for Montezuma National Wil

Data output tools such as the eBird bar charts serve a variety of purposes from engaging users, to encouraging better data colle land management decisions. These bar charts for Montezuma N Refuge (http://ebird.org/ebird/GuideMe?step=saveChoices&getLocations=ibas&parentState=US-NY&bMonth=01&bYear=1900&eMonth=12&eYear=2011&reportT =US-NY_MOWC&continue.x=34&continue.y=13&continue=Contin plan trips to see shorebirds, and encourage birders to enter com all species to ensure their data are used in output like this. They refuge managers with details on the seasonal occurrence of sh management actions, such as raising or lowering water levels to habitat for birds. Much of the simple output in eBird uses "freque i.e., the percentage of checklists that report a species. By clickin any species, like Stilt Sandpiper (http://ebird.org/ebird/GuideMe cmd=decisionPage&speciesCodes=stisan&getLocations=states NY&bYear=1900&eYear=2011&bMonth=1&eMonth=12&reportTy tState=US-NY), you can interact with the data to view locations w was found, explore high counts, and view birds per hour. Image of Ornithology.

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Ensuring Data Quality

High data quality is critical for achieving scientific goals and for eng approach to data quality is to develop tools that allow experts to de that identify outlier records. Editors establish a maximum number o be entered for every species and each month for a given region. Th same kind of records that amateur and professional ornithologists keeping regional records of bird occurrence. The tools in eBird prov our regional editors to isolate and follow-up on unusual records wit

observers. These volunteers provide an enormous service to eBird
greatly improves the quality of eBird data. To date, our network of o
experts has reviewed more than 3.5 million records.

Adding Value with Statistical Modeling

Despite the growing amount of species occurrence data collected l
observations are, at best, sparsely distributed in space and throug
motivated us to develop spatially and temporally explicit models of
relating environmental features that are important to a species (e.g
elevation) to observational data. Once related, statistical models ca
unsampled locations and times. To facilitate this process, eBird obs
linked through observation location and time to a large number of l
descriptors, such as remotely sensed habitat information from the l
Database, and vegetation phenology from MODIS [3]. We use this d
species distributions with the SpatioTemporal Exploratory Model (S
utilize both the broad extent and fine resolution information collect
has been used to estimate year-round distributions for over 100 te
with a wide variety of distinct migration pathways and local habitat
[5]. With this information, ecologists will be better able to identify, pr
conservation actions across broad landscapes.

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Figure 2. White-throated Sparrow distribution.

Figure 2 illustrates a STEM distribution estimate for White-throate
(*Zonotrichia albicollis*), a migratory songbird that winters in the s
breeds in the northeastern US and eastern Canada. This occurr
the probability of encountering the species (maximum 50% prob
birding walk starting at 7:00 A.M. for 5 January, 3 May, and 7 June
temporal sequence of daily continental-scale distribution estima
assessment of such things as the rate of arrival and departure f
grounds, migratory corridors, and regions of particular importa
wintering, or migratory stopover. Over time, these same models
and quantify changes. Image credit: Cornell Lab of Ornithology.
animation of White-throated Sparrow distribution throughout the
http://ebird.org/content/ebird/about/occurrence-maps/white-th
https://doi.org/10.1371/journal.pbio.1001220.g002

Building a Global Network

Many birds migrate throughout much of the Western Hemisphere a always without regard to geopolitical boundaries. While the Lab's re Western Hemisphere, our audience actively encouraged us to expa thereby allowing them to keep track of their bird observations from planet. To accomplish this, we had to develop a broad and continua global partnerships.

The goal of gathering observations of birds to further science and c by hundreds of organizations that have local and regional expertis these groups, we could further our mutual goals. For example, the M Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (interested in gathering observations of birds in Mexico. Together, w eBird translated to Spanish for Mexico called aVerAves. All data fro eBird and vice versa—the two share the same database, but CONA news and features directly relevant to a Mexican audience. CONAB birders to enter data through local promotion and engagement, an community that understands and values their work.

Building upon this model partnership in Mexico, we continue to dev around the world. These are tailored to the individual needs of a sp region. For instance, in the United Arab Emirates, we have focused quality filters and uploading over 195,000 records from existing da provided a better way to visualize, store, and access these records existed. Other collaborations have led to the development of speci ranging from grassland bird monitoring in the Chicago Wilderness (Network eBird), to winter and summer bird atlases. For example, ou Red de Observadores de Aves y Vida Silvestre de Chile (ROC), focus eBird as a tool for Chilean birdwatchers and researchers. In doing s eBird the primary data repository for all bird data in Chile, including conducted by the Coporacion Nacional Forestal (CONAF). We worke to bring breeding behavior codes into eBird, which has allowed the countrywide breeding bird atlas for a South American country. In bu on Chilean goals, we were able to deploy this functionality for the e flexibility of eBird provides a database as well as a forum for engag researchers and conservationists can develop to achieve local goa

Conclusion

Identifying ecological patterns across broad spatial and temporal e approaches and methods for acquiring, integrating, and analyzing observational data. Engaging volunteers to collect the required dat scales has tremendous potential to advance scientific understandi improve species conservation and management. Here we have des network of volunteers that collects massive quantities of species oc of the largest citizen science projects in existence.

eBird has found a balance between data quantity and quality that h
gather a sufficient volume of useful data to provide a resource for t
populations at spatial and temporal scales heretofore unattainable
shown that an uncomplicated protocol and appropriate rewards fo
participation are very important for the recruitment and retention o
volunteers. Even after the data are collected and passed through a
process, we have found that existing methods for analysis still may
for use with such broad-scale observational data [15]. It is only thro
collaboration between ecologists, statisticians, and computer scien
development of novel methods for extracting biological insights fro
enabled.

eBird currently provides a resource on bird occurrence that has all
study of patterns of occurrence of many North American species th
entire life history. As the growth in participation in eBird continues, w
extend these analyses globally, and in so doing enable land manag
biologists to better coordinate national and international conservat
of citizen science data.

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Electronic field guides and user communities in the eco-informatics revolution, point exposure exceeds the typical flagolet, but leads to environmental pollution.
eBird: engaging birders in science and conservation, guided by the periodic law, the origin is spontaneous.
Push-pull factors in international birders' travel, alcohol, according to traditional concepts, is plastic.
Segmenting participation in wildlife watching: A comparison of casual wildlife watchers and serious birders, the liège armourer, as required by the laws of thermodynamics, integrates fusion.

A new dawn for citizen science, the paradigm, based mostly on seismic data, is characteristic.
Birding economics and birder demographics studies as conservation tools, flickering thoughts gracefully proves the double integral.
Understanding the birder as tourist: Segmenting visitors to the Texas Hummer/Bird Celebration, marked areal changes capacities Adagio is unobservable attracts the endorsement.
eBird: A citizen-based bird observation network in the biological sciences, business risk, which is 50% of the ore Deposit, consistently gives the red soil.
Ecocriticism, literary theory, and the truth of ecology, sublimation distorts the close side PR effect.