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PERSPECTIVE

Nature apps: Waiting for the revolution

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Abstract Apps are small task-orientated programs with the potential to integrate the computational and sensing capacities of smartphones with the power of cloud computing, social networking, and crowdsourcing. They have the potential to transform how humans interact with nature, cause a step change in the quantity and resolution of biodiversity data, democratize access to environmental knowledge, and reinvigorate ways of enjoying nature. To assess the extent to which this potential is being exploited in relation to nature, we conducted an automated search of the Google Play Store using 96 nature-related terms. This returned data on ∼36 304 apps, of which ∼6301 were nature-themed. We found that few of these fully exploit the full range of capabilities inherent in the technology and/or have successfully captured the public imagination. Such breakthroughs will only be achieved by increasing the frequency and quality of collaboration between environmental scientists, information engineers, computer scientists, and interested publics.

Keywords Mobile apps · Applications · Citizen science · Biodiversity · Biogeography · Digital conservation

INTRODUCTION

Humanity is in the midst of an ‘information revolution’ with the potential to generate profound changes that reach into almost every component of everyday life (Sliwa and Benoist 2011; Saylor 2012). ‘Apps’ (an abbreviation of software applications) are a core-component of the information revolution, linking the technological forces of cloud and mobile computing, social networking, and ‘big data’ to transform mobile devices into sophisticated sensors and powerful computers (Chih-Chin and Huang 2012). Indeed, the latest generation of smartphones has unprecedented potential to alter the way we interact with each other and our immediate environment. Their potential transformative effects even extend to the natural world, modifying how we appreciate, use, and conserve wild places, animals, and plants.

The opening of Apple ‘iTunes App Store’ (2008) and Google’s ‘Android Market’ (2009) has allowed almost instantaneous access to these low-cost, easy to install, and task-specific programs. The size of this market is staggering: In 2013, nearly 968 million smartphones and 195 million tablet computers were sold (Gartner Inc. 2013a, b). Apps, and the smartphone and tablet devices on which they run, are rapidly becoming indispensable adjuncts to the everyday lives of citizens worldwide and an integral and often unnoticed part of the social fabric (Burkhardt et al. 2002; Chih-Chin and Huang 2012).

The proliferation of apps and their potential uses is unprecedented and exciting. Soon, anyone within 50 km of a transmission mast and 10 h of an electric power source will have almost the same potential to engage with knowledge, data, software, and networks as a reader of this article sitting in a comfortable office or university library. Nature conservation is beginning to engage with these dynamic technologies and some apps are emerging that illustrate the vast potential of this ubiquitous technology to transform the interaction of society with nature. Here, we use data from a 2013 survey of nature-related apps and examples of state-of-the-art conservation/environmental science apps to support our argument that (1) apps have the potential to revolutionize nature conservation and environmental science; (2) this transformative power is yet to be fully exploited; and (3) environmental scientists and conservationists need to better engage with information engineers, software developers, and potential users if they want to reap the enormous scientific and social benefits of this new form of human–nature interaction.

THE APP SURVEY

We conducted a randomized English-language data scrape (automated data collection) from Google Play Store between February and April 2013 using nature-related search words. Our decision to restrict the search to Android apps was based on pragmatism: the Apple iTunes store (iOS apps) cannot be easily scraped. Furthermore, we assumed that the Google Play Store would provide a broadly representative sub-sample of the population of nature-related apps, given the combination of cheaper Android hardware, lower entry barriers for Android App developers, and the wider global reach of Android compared to iOS.

In order to adequately search a genre of apps as broad as "nature," nature-related search terms were generated using word clouds created from the names and descriptions of a range of nature recreation, reference, and citizen science apps chosen to reflect the diversity of themes, categories, and functionality available at the time of the survey. We identified 96 nature-themed search terms which we grouped into different themes (see Table 1).

Our scrape searched for each of the 96 terms in the app name and the 'short description.' It then automatically entered the URL of each app identified by the search terms and compiled (into an excel spreadsheet) the following data: app title, app version, developer name, category, description, rating score, number of installs, and 'also installed apps.' To stay within the search requests limits of the Google Play Store, we added a random wait-time (between 2 and 10 s) between queries. To accelerate the scrape and to avoid the Google service of personalized search results—which would have generated bias—we routed our searches through parallel proxy servers. The large number of search terms we employed meant that the scrape took nearly 3 months to complete.

We retrieved 36 304 apps that were manually reviewed by the authors working together to remove non-nature-related apps—semantic complexity precluded fully automated pruning. Through this process, 6301 apps were identified as nature-themed.

The ~6300 nature-themed apps[1] were then assigned to one or more of six major use categories following an interactive process of automated keyword classification and manual review. The six categories were (1) Personalisation apps (sub-divided into wallpaper, ringtones, clocks); (2) Gaming apps (games, quizzes, puzzles); (3) Nature recreation apps (birding, fishing, hunting, diving, natural history, mycologists, aquarists); (4) Site visits apps (national parks, zoos, aquaria, botanical gardens, museums); (5) Reference and News apps (field guide, novel, atlas, reference, children's book, photo books, magazine); (6) Citizen Science apps (surveys, sightings).

[1] dataset doi: 10.5072/bodleian:xp68kk22h.

Table 1 Full list of words used to search the Google Play Store grouped according to themes

Theme	Search words
practices	'observations,' 'sightings,' 'submissions,' 'recording,' 'collecting,' 'log,' 'track,' 'watching,' 'watch,' 'survey,' 'citizen science,' 'guide,' 'spotting,' 'monitoring,' 'viewing'
tools	'data,' 'project,' lists,' 'checklists,' 'GPS,' 'atlas'
pastimes	'birding,' 'hunting,' 'fishing,' 'angling,' 'ringing,' 'safari'
entities	species,' 'biodiversity,' 'wildlife,' 'animal,' 'critters,' 'birds,' 'plants,' 'flowers,' 'trees,' 'mushrooms,' 'fungi,' 'mammals,' 'bat,' 'reptiles,' 'amphibians,' 'fogs,' 'snakes,' 'fish,' 'sharks,' 'turtles,' 'insect,' 'bugs,' 'beetles,' 'butterflies,' 'fossil,' 'dragonfly, 'dolphin,' 'whale,' 'seal,' 'panda,' 'lion,' 'tiger'
disciplines	'ecology,' 'ornithology,' 'zoology,' 'botany,' 'etymology,' 'herpetology,' 'natural history,' 'ichthyology,' 'paleontology'
processes	'invasive,' 'extinction,' 'conservation,' 'protection,' 'vanishing'
places	"field,' 'habitat,' 'national parks,' 'conservancy,' 'nature reserve,' 'state park,' 'zoo'
biota	'marine,' 'oceans,' 'reef,' 'freshwater,' 'forest,' 'rainforest,' 'wetland,' 'river,' 'stream,' 'creek,' 'jungle'
frames	'nature,' 'environment,' 'ecosystems,' 'wilderness,' 'green'

NATURE-THEMED APPS: WHERE ARE WE NOW?

As anticipated, the number of nature-related apps available in the Google Play Store (6300+) was tiny in comparison to all available apps (1 million+). The two most frequent categories of nature apps were personalization apps such as wallpapers/ringtones (2579 apps, 40.9 %), and games (2351, 37.3 %). There were also substantial numbers of books and reference apps (1223, 19.4 %), and nature-based recreation support apps for hunting, fishing, birding, etc. (755, 12.0 %). The least frequent categories were nature visitor attractions apps (244, 3.9 %) that covered parks, zoos, museum, aquaria, and botanical gardens and, finally, citizen science apps (33, 0.5 %). Note that some apps appear in more than one category.

In the largest three categories (personalization, games, and reference apps), we found that developers had either added a nature 'product' to generic personalization or game coding architectures, or transferred established nature book formats to mobile digital versions with relatively simple add-ons (e.g., incorporating audio song files into bird field guides).

The high prevalence of nature-related games in our survey is unsurprising given that gaming apps are the top growing categories in worldwide mobile app sales development (Hill 2014). Highly successful gaming franchises such *Angry birds*, *Flappy bird*, and *Fish Live* illustrate the potential of animals for gaming animation. Indeed, Sandbrook et al. (2014) noted that the affordances of smartphone platforms (e.g., multiple sensors, 3D visuals, tri-axial motion controls) offer exciting potential for the development of digital conservation games—defined as those that support education and behavioral change, fund-raising, and/or research, management, and monitoring. The most downloaded nature-related game apps were those replicating hunting experiences, e.g., *DeerHunter 3D* (GluMobile) and *Duck Hunter* (Gerhard Marce). This type of game generally involves accruing points for killing or catching animated animals, which can then be 'spent' on better weapons. A similar approach was adopted in conservation education in games such as *Poacher Terminator* (Lubiceju), where the goal is to acquire weapons to kill evil poachers; *Camera Birds* (FLARB) which involves snapping photos of birds in a virtual forest, and; *Wounded iWhale Rescue* (GPimports) where that goal is to 'save' (i.e., catch) whales. *Deep water hero* (National Wildlife Federation) is an example of a puzzle format being applied to an environmental issue; in this case, working out how to break up an oil slick to save animals. From a conservation perspective the stand-out game app was probably the Korean developed *Tree Planet* which challenges players to plant, nurture, and protect a tree. Once they have reached level 7 they can apply for a real tree to be planted on one of the project's three reforestation sites. *Tree Planet* was the only 'mixed reality' game app in our survey, i.e., one that blended the virtual and physical worlds (Bonsignore et al. 2012). Overall our survey of nature-related apps revealed limited innovation in digital games, reinforcing Sandbrook et al.'s (2014, p. 6) observation that "most conservationists know little about digital gaming" and suggesting that nature-based enterprises have yet to recognize the potential this medium offers.

We found evidence of increased functionality and innovation in apps designed to support nature-based recreation and visits to nature attractions. Such apps frequently integrate the smartphone's GPS and compass functionality with map caching to support navigation, to record observations, and to send alerts of interesting sightings to other users. Hunting-support apps typically emphasized navigation and route mapping, while fishing and birding-support apps emphasized geo-locating the user's sightings (log books) and reporting or plotting the recent sightings of others. Most recreation support and site visit apps included access to information resources (e.g., weather, tips, regulations) and options to cache maps, upload photos, and share field knowledge (e.g., wildlife sightings, successful hunting, or collecting locations) via social media. Several hunting apps even featured audio lures to attract game species. In our opinion, the stand-out app in this category was *ActInNature Hunting* (ActinNature Company) which innovatively added a social dimension to the above suite of hunting functionalities. Specifically, it utilizes the smartphone's GPS, accelerometer/gyroscope and magnetic compass to provide the user with a real-time 3D visualization of their position relative to fellow hunters using the app.

Apps associated with visiting attractions typically emphasized routes and location mapping, with a tiny minority (e.g., London's Kew Gardens) providing augmented reality interpretation of exhibits. The potential for a step change in environmental interpretation at visitor sites could be most clearly seen in apps such as *Leafsnap* (Columbia University) that uses image recognition software to automatically identify tree species from the leaves, and augmented reality apps such as *Coral RKV* (Mark Billinghurst) and *Zoo-AR* (Geomedia, Inc.) that animate 2-D posters and overlay/link to information resources. Future development of these technologies and their integration into wearable AR technology (e.g., Google Glass, Oculus VR) have the potential to transform educational- and curiosity-driven engagements with nature.

Of the 755 recreational-support apps in our survey, 219 had the ability to log sightings, but only 25 had the facility to upload these to biodiversity monitoring schemes and/or National Biodiversity gateways. Surprisingly, only half (17) of the 33 citizen science apps we identified had this functionality. Furthermore, only two apps in our sample, *OzAtlas* (CSIRO) and *Find and log animals and plants* (Global Biodiversity Information Facility) made biodiversity data archives freely available to citizens and allowed users to contribute their own sightings. These two apps contribute to broader moves to democratize the production of knowledge (see e.g., Lave 2015) by empowering citizens to contribute data to authoritative data sets upon which substantive decisions are based.

The majority of the 33 citizen science apps focused on recording target species (e.g., *Great Koala Count*), taxon groups (e.g., *Bugs Count*), invasive species (e.g., *Plant tracker*), or diseases (e.g., *LeafWatch*). Of these, most simply combined a basic field guide and survey form with the location and photo capture and data-upload functionalities of smartphones. A small number (notably *iSpot, iNaturalist, and Project Noah*) were integrated in web-platforms that use crowd-sourcing to build biological literacy, community, and prestige among peer groups. For example, *iSpot,* managed by the Open University, allows citizen recorders to request others members of the *iSpot* community to confirm identifications and/or identify unknown species (Silvertown 2009).

Once again, there were only a small number of citizen science apps that demonstrated the potential of app technology to extend boundaries of biodiversity science, monitoring, and citizen engagement. The most innovative (in terms of extended functionality) of these were probably *iBat* (Indicator Bats Programme, Zoological Society of London) and *New Forest Cicada Hunt* (University of Southampton). These were among the first nature apps to integrate crowd-sourcing, sensor capabilities, and supercomputer power. *iBat* directly links the smartphone sound card to an (hardware add-on) ultrasonic bat detector, enabling users to record bat calls along transects and upload the geo-referenced data to an online database. This database then uses an open access classification tool (iBatsID) that deploys ensembles of artificial neural networks (eANN's) to classify time-expanded recordings of bat echolocation calls from 34 European bat species (see Walters et al. 2012). Recordings not suited for machine-identification are submitted to a Zooniverse Real Science online project[2] for crowd-sourced identification and discussion.

Originally developed by astronomers to help manage 'data deluge,' Zooniverse is a collection of online citizen science projects with over 600 000 registered users (Borden et al. 2013). These projects deploy the advanced pattern recognition capacities of the human brain to engage citizen volunteers in classifying, extracting, and discussing visually reproduced data, such as galaxy photos and ancient documents. A similarly innovative approach was taken by the *Instant Wild* app (Zoological Society of London), which provides links to remote video monitoring cameras and asks users to view the video streams and identify the remotely recorded animals. If, as seems likely, the use of 'conservation drones' carrying video sensors takes off (Koh and Wich 2012; Sandbrook 2015), such apps may become vital for analyzing the enormous amounts of video footage captured.

New Forest Cicada Hunt also deploys a combination of machine learning and smartphone functionalities to extend human sensing capabilities. The app integrates a hidden Markov model (HMM) that is able to detect and identify the 'lost' English cicada and six species of British grasshopper and cricket (exploiting the fact that the sensitive microphones of modern smartphones can easily detect frequencies that are at the limits of human hearing) (Zillie et al. 2013). Cyclists and walkers simply switch on the app when they are in the countryside and are alerted if a sound matching the profile of these species is detected. At this point, the human user is requested to use their mobile device to make a recording, after which they upload it onto the project database. The *New Forest Cicada Hunt* app represents a significant step toward achieving real-time automated acoustic species detection and identification via a smartphone and provides a unique platform for everyday citizens to participate in the exciting practice of species rediscovery (Ladle et al. 2011).

The 'holy grail' in this area of app development would be an automated bird call identification app. Such an app would have the power to transform the way citizens enjoy and interact with nature, taking a highly specialist skill (bird call identification) and making it available to anybody with a smartphone and an appropriate microphone. More generally, apps that identify and index animal sounds could potentially invigorate the nascent science of soundscape ecology, helping scientists to classify and even assess the health of ecosystems based on their acoustic characteristics.

Our survey identified two types of scientific research-support apps with exciting future potential: (i) apps that support or interact with add-on sensors to extend the capabilities of smartphones, and (ii) apps that support data collection for a particular purpose or situation. As already mentioned, ultrasonic add-on microphones enable apps such as *iBat* to capture bat echolocation calls. Apps such as *AR Free Flight* enable users to control and stream video from micro-drones, while DIY spectrometer kits[3] offer the potential to develop pollution monitoring apps. As the range of sensor add-ons expands and prices begin to drop, we anticipate a range of new apps that will make once sophisticated research techniques accessible to a much broader range of researchers and the general public.

Bespoke data collection apps interact with web-based survey forms (incorporating questionnaires, photos, audio data, etc.). Such apps enable long-distance collaborations involving the collection, analysis. and reporting of data. A leading example from our survey was *Sapelli*, developed by the EcCitesS research group at the University College of London. This app is integrated into a web platform for open-source data collection and sharing that, via the app, converts the smartphone screen to an icon-driven interface. Critically, the simplicity of the interface empowers both literate and non-literate field workers in Africa to collect sophisticated environmental data (using pictorial decision trees). *Sapelli* also features coding that conserves battery life and optimizes data transmission based on available networks and bandwidth. Returning to the theme of

[2] http://www.batdetective.org.

[3] http://publiclab.org/wiki/spectrometer.

hardware add-ons, the UCL group has developed a smartphone changer that can run from a cooking pot!

THE FUTURE OF NATURE-THEMED APPS

Our Google Play Store survey clearly illustrated the enormous diversity of nature-related apps. However, despite large numbers of app developers appropriating nature-based themes, it is clearly premature to claim that we are in the midst of an app-based revolution that is transforming how we relate to and interact with the natural world. Nevertheless, we would argue that this transformative potential exists and can be clearly seen in the small number of apps that are exploiting the latent functionality of mobile computing devices and recent technological advances in data storage, machine learning, and informatics. In our view, the future of nature and conservation apps lies in their ability to harness the power of cloud computing and 'big data' analytics, incorporating the sensor and computing affordances of smartphones (with hardware add-ons) and human capacities (cf. Chapron 2015; Kelling et al. 2015 in this issue). Such apps have the power to turn a smartphone into a sort of human appendage, creating a kind of 'human–machine hybrid.'

Our survey identified three areas where this potential is starting to be realized: (1) real-time 'machine learning supported' acoustic species identification apps; (2) augmented reality integrated into nature visitor attraction apps; and (3) apps that are linked to add-on sensors designed for ecological research. There are currently a very limited number of apps in these areas, possibly due to the difficulty of putting together app development teams with the appropriate range of technological knowledge and practical know-how to create innovative apps with high levels of functionality. Moreover, the holders and promoters of nature-related study and conservation are predominantly government agencies, NGOs, and publishers who typically employ generic app developers to simply improve the reach and efficiency of their existing practices and resources. Thus, there is a lack of incentives and resources to invest in technological developments that may unsettle established institutional arrangements. There may also be concerns about the potential negative consequences of nature-related apps and how to govern their use. For example, apps that support birding, hunting, and mushroom collecting have the potential to increase disturbance/exploitation of rare species though the use of digital lures, coordinated hunting, and sharing of site information.

In our view, kick-starting the next generation of nature-related apps will require (i) investments in the development of high-spec open-source algorithms and APIs (e.g.,for automated sound identification and contributing sightings to biodiversity recording schemes); (ii) increased financing for creative teams and partnerships (e.g.,with the gaming industry; see also Joppa 2015) to produce high-profile 'concept' apps that extend ways of engaging with nature and landscapes; and (iii) public investment in large-scale demonstration projects that develop, apply, and test the potential of smartphones and their associated technologies in the study, enjoyment, and monitoring of nature.

What is clear to us is that universities and other advanced research institutions need to be at the center of nature app development (Galan-Diaz et al. 2015). This is because they have the computer scientists, information engineers, and ecologists who are capable of meeting the challenges of working at the interface of natural, social, and technological complexity. They also have the computing power, and open-source ethos to meet the above requirements, along with the independence and societal standing to help address the ethical and governance issues that will surely arise.

CONCLUSIONS

The rise of nature conservation as a cultural, scientific, and policy imperative was one of the defining features of the twentieth century (Jepson and Ladle 2010). If humanity is embarking on an 'information revolution,' then it is vital for nature conservation to engage with new technologies in progressive and experimental ways. Failure to do so could comprise the future of conservation as a cultural force. Despite the rapid global expansion of app-driven mobile computing, we conclude that nature-related interests have yet to engage with the affordances and potential of these technologies in any significant way.

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