Special Series: Natural History in the Digital Age

Developing Mobile Tools for Biodiversity Informatics and Natural History Education

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The increasing availability of mobile educational technologies provides new opportunities for biodiversity research, education, and public engagement with the natural world. However, these tools are often time-consuming and expensive to create. Here we describe the The Butterfly Guide: Butterflies of the Sacramento Valley, Delta, and San Francisco Bay Area*, a mobile natural history application with which users can collect and share species observation data. The app is free, but perhaps more importantly, documentation and source code are available on request. We describe our aim for* The Butterfly Guide *to serve as a template for others interested in creating similar tools, and discuss the future of such digital technology for enhancing natural history observation and experience.*

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Introduction

In the midst of a global biodiversity crisis and human-driven changes in the composition and function of the earth's ecosystems, the documentation of the world's organisms is one of the primary scientific goals of this century and is made increasingly possible by advanced technologies in data management and analysis (Wilson 2000, Guralnick and Hill 2009). The digitization of museum and herbaria records is underway around the globe, and numerous online biodiversity databases have been created to serve as data repositories.

Several of these projects recognize the opportunity to include citizen scientists in the research process. Such biodiversity data initiatives present opportunities in both data management and education, with the potential to use available technologies such as online databases and smartphones for citizen science-based data collection, data-intensive scientific research, and natural history education (Hey et al. 2009, Kelling et al. 2011).

Many features already included on smartphones, such as built-in cameras, data storage capacity, and GPS capabilities make them especially useful for field-based education tools such as electronic field guides (Newman et al. 2012). Multiple field guides can be downloaded to the same device for easy portability, searchability, and access, and numerous guides to plants and wildlife have been released on the Apple and Android application (app) markets in recent years. Several guides to birds (Appweavers Inc. 2013, Sibley Guides 2013) have been especially successful, as they take advantage of audio capabilities to include birdsongs in addition to the more standard features. The Audubon Society has released region-specific field guides for a variety of taxa across North America. Other projects are using smartphone apps for users to document local wildlife, such as Project Noah (Networked Organisms 2012), a citizen science-based project that aims to broadly document the world's organisms, and BirdLog (The Cornell Lab of Ornithology 2010), a data collection app that integrates with the popular eBird database (Wood et al. 2011) developed by the Cornell Lab of Ornithology.

The opportunities for using mobile technologies for educational, scientific, and conservation purposes are vast. However, while many research projects and biodiversity initiatives could benefit from data collection apps, the development of these tools can be

costly and time consuming. These problems can be easily addressed by developing software tools that are open-source, collaborative, and free, much in keeping with the current trend toward Open Science in scientific research and publishing (Wald 2010). Indeed, some developers of educational apps have already made their source code freely available to other researchers, educators, and developers (e.g., Palumbo et al. 2012), and this is likely a trend that will continue as more natural history practitioners incorporate electronic tools into their courses and research.

Here we present an Apple mobile operating system (iOS) app for which all content and source code are freely available to practitioners interested in developing similar non-commercial natural history education tools. *The Butterfly Guide* provides a template for regional field guides with data collection capabilities and potential for use in citizen-science projects. Despite the app's narrow geographic and organismic foci, the architecture of the app is such that the biological content can be replaced with relevant information for other regions and/or taxa. The goals of *The Butterfly Guide* are to:

1. Maximize public participation in scientific data collection by creating contributory tools;

2. Contribute accurate distribution, phenology, and abundance data to biodiversity databases;

3. Engage students and citizens in the outdoors;

4. Provide free development materials for the creation of other natural history field guides for different organisms/regions;

5. Promote discussion of the appropriate use of technology in field-based natural history education courses.

The basic features and functions of this app are described below, followed by a discussion of the major challenges associated with developing, maintaining, and using similar apps.

Methods

The majority of the app's biological content was taken from Art Shapiro's Butterfly Site (http://www.butterfly.ucdavis.edu) and is licensed under a Creative Commons Attribution-ShareAlike 2.5 License. This content was reformatted and revised as needed for completeness and continuity. Additional biological content was drawn, with permission, from the

Butterflies and Moths of North America website (http://www.butterfliesandmoths.org), and several butterfly field guides served as additional references (e.g., Glassberg 2001, Shapiro and Manolis 2007, Opler et al. 2011).

As an iOS application, *The Butterfly Guide* was developed using the Apple XCode Integrated Development Environment. The programming language for iOS applications—as well as for the iOS application programming interface, CocoaTouch— is Objective-C, an object-oriented C-based language that was used for all source code. Structural features were designed to include "Species Pages," "Family Pages," a "Journal Archive," "Education Resources," and "Browse and Search Functions." Each feature is described briefly below.

With a total of 117 species included in the app, "Species Pages" comprise the majority of the content of *The Butterfly Guide*. Each page includes several photographs of different life history stages (e.g. egg, larva, adult), with corresponding photo credits and captions (all photographs / artwork copyrighted to their original owners; Figure 1; note to readers: all figures are given as links to .png files rather than as embedded images in order to provide them at as high of a resolution as possible).

Morphological descriptions are provided for the purpose of field identification, and basic biological information is included, such as larval host plants, adult nectar sources, habitat types, seasonality, life history descriptions, and similar/commonly confused species.

Finally, the species descriptions include several internal and external links. Internal links include links to glossary terms, other species pages, and family pages. External links connect to other butterfly websites (e.g., those cited above), other databases such as those for host plant records in the CalFlora database (http://www.calflora.org) or for insects (http://www.antweb.org), Wikipedia entries (http://www.wikipedia.org), and photo contributors' websites.

Other structural features include "Family Pages," which are provided for the six butterfly families included in the app. These present short, 1-2 paragraph descriptions of the general morphology, biology, and distribution of each family (Figure 2).

The "Journal Archive" provides a means for users to record their own species observations. Specifically, users can create independent "Collections" with relevant

metadata such as location, data collectors, date & time, and an optional field for notes (Figure 3). Once a "Collection" is created, species records can be added by entering species names and counts. Photos can be taken from within the app and connected to individual species records, providing an important feature for data validation.

"Education Resources" continue to be added to, and to-date include a "Glossary" of biology, ecology, and entomology terms; an "Anatomy Page" depicting basic Lepidopteran anatomy (Figure 4); and the "Species" and "Family Pages" themselves. These resources could be expanded to include activity suggestions, biology curricula, and even educational games and challenges. Finally, "Browse" and "Search" functions allow users to navigate through the app.

The "Search Function" can be used to identify a particular butterfly by entering the common or scientific name in the search bar, or if the name is unknown users can enter the family name or color (Figure 5). Each search produces a list of butterflies that meet the search criteria, along with a thumbnail image of each potential species match.

The "Browse" function provides a scrollable list of all species, sorted alphabetically by scientific name, common name, family, or color (Figure 5).

Challenges of Technology for Natural History Observation

In addition to limited time, financial resources, and/or programming skills, there are many obstacles and challenges that need to be considered when developing an app such as this, and there are many ways that the app presented herein could be improved or expanded. Even before development begins, availability of information can be a major limiting factor, as acquiring the content for such as app can be difficult and time-consuming.

The Butterfly Guide used an existing regional database, *Art Shapiro's Butterfly Site*, as its primary source of content, but in the absence of analogous resources, an app like this would be a significant challenge to create. Other major challenges to the development and both short- and long-term utility of such apps are discussed below and include licensing, completing the data cycle, app maintenance, and project longevity.

With the exception of publicly available content (i.e., under Creative Commons Licensing), it is essential to obtain written permission for the use of photographs,

weblinks, and artwork even if permissions had already been granted for use of these photographs in other publicly available websites. Thus, substantial effort is entailed in contacting all source contributors individually and obtaining written permission to use their materials in the app. *The Butterfly Guide* app is licensed in three parts. Photograph and artwork contributors retain the copyrights to their original work and therefore their permission must be obtained for further use of their material.

The biology content of the app is licensed under its original Creative Commons Attribution-ShareAlike 2.5 License. Finally, the source code and development materials are copyrighted to app designers (the authors of this paper), and are freely available by request. This does not, however, mean that they are Open Source, which would allow for code to be shared, altered, and redistributed freely, including for commercial purposes. This would contravene an aim of *The Butterfly Guide* to serve as a template for developing free, non-commercial education materials.

Unfortunately, the Creative Commons Attribution-Non-Commercial License, which allows for materials to be altered and redistributed but does not allow the resulting products to be sold, does not apply to computer software or source code. Therefore, because there is no good analogous license for software and source code that would prevent commercial reuse of the development materials, for *The Butterfly Guide* these are only available by request and upon agreeing to the terms of non-commercial reuse.

In the interest of expanding access and minimizing the use of proprietary and closed-source software, it would be useful for an Android version of the app to be developed. Including additional high-resolution photographs would allow for a more fully functional tablet version as well.

In order to be fully functional, mobile data collection apps should integrate with online databases to upload, validate, and store observational data. One of the major advantages to using mobile apps in the collection of biodiversity data is that collection methods can be standardized and corresponding metadata can be captured automatically. Several such biodiversity databases exist already and include citizen scientists as mobile data collectors.

As a public data collection tool, a primary aim of *The Butterfly Guide* is to "complete the data cycle" by facilitating the seamless acquisition, synthesis, and dissemination of biodiversity information. In addition to

archiving individual "Collections," the app encourages users to share their observations by manually uploading observations and a validation photo to the *Butterflies and Moths of North America* website.

Ideally, however, a standalone website for apps like *The Butterfly Guide* should be developed, allowing users automatic upload of photos, notes, and metadata to an online database. An open access web database would enable data sharing and validation (in a way that the "Collections" function currently does not), while allowing users to connect locally to organize collecting efforts and to share education materials, maps, and other web resources. Future modification of *The Butterfly Guide* could include adaptation of the "Journal Archive" to allow users to automatically upload their photos and records to relevant web databases, even directly from remote field sites. "Education Resources," in particular, could be expanded to include activity suggestions, curricula designed to meet state standards, information about sampling issues and methods, and informal educational modules.

All of these suggestions raise the question of the long-term maintenance of the app and longevity of associated projects. Indeed, the development of any community-based project faces considerable challenges in staying updated and relevant in the absence of long-term funding and staff dedicated to its maintenance and curation. To date, minimal maintenance has included revising development code as new iOS versions are released and optimizing functions for processing speed. Currently, the app has been publicly available since November 2012, and the current developer's license will expire in May of 2015, whereupon the project will be reevaluated and perhaps extended. In the meantime, we hope to share the app with other educators and researchers for adaptation for their own education projects.

Facilitating the incorporation of digital technologies into natural history observation and education, whist one of the aims of our app, warrants critical reflection. Increased consumption of electronic media is well understood to be a powerful contributor to nature deficit disorder among children (Pergams and Zaradic 2006, Charles and Louv 2009), while increased time spent indoors with television, social media, computers, hand-held devices, and other instruments of passive entertainment contribute to the growing alienation of many people from the natural world (Trombulak and Fleischner 2007, Rock 2014). Furthermore, many of us turn to natural places for a much-needed respite from our increasingly technological lives; it is no wonder we are hesitant to adopt technology in our field-based

endeavors. However, one could argue that we already are resident in a technologically mediated natural landscape, with digital cameras, advanced-optics binoculars, and water-proof notepaper in hand.

The issue for discussion is perhaps not whether digital tools have a place in natural history education, but how we can design and implement these tools so that they might enhance more than they detract from the natural history experience. It is our hope that, as a first step, educators, researchers, and practitioners will begin to explore by adopting and creating digital field tools, such as *The Butterfly Guide* and other identification apps. We suggest that it may be simultaneously useful to develop a list of "Best Practices" that ensure that digital tools never interfere with or replace direct, intimate interactions with nature, but rather serve as a way to share and inspire new audiences to connect with the natural world. This collection of guidelines could be developed through contributions to this series and through the JNHEE's online forum, http://naturendigitalage.wordpress.com, dedicated to debate and discussion of Natural History in the Digital Age. We look forward to this conversation. In the end, including digital technology in natural history observation and experience may be one of the most powerful ways we can revitalize the field of natural history and restore it as a fulfilling and highly relevant public practice in the 21st century.

Acknowledgements

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