Personal BioBlitz: A New Way to Encourage Biodiversity Discovery and Knowledge in K-99 Education and Outreach

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ABSTRACT

Broad and detailed knowledge about common species in everyday life has decreased among the public. Even biology researchers may be largely unaware of our everyday biodiversity. To counter such 'species blindness' and create long-term excitement and learning about the biodiversity we see every day, we arranged 76-day BioBlitzes at Rutgers University (New Jersey, USA) in 2014 and 2015 where participants identified and listed all species they discovered. The result was 7270/11748 observations from 30/78 participants and 7/13 countries, including 3458/3057 unique taxa, 91%/99.9% identified to species and 80%/54% listed only by one person (2014/2015). Observations of organismal groups did not strongly correspond to number of estimated species worldwide, but appeared to be related to perceived charisma, body size, and organism mobility. Participants reported increased ability to 'see' species and to identify new groups, learning new tools of species identification and strongly increasing their biodiversity knowledge and eagerness to learn more.

Keywords: bioblitz, digital tools, education, inventory, species

INTRODUCTION

We decided to create a Personal BioBlitz project in the Department of Ecology, Evolution and Natural Resources at Rutgers, the State University of New Jersey to encourage and challenge each other to learn about the biodiversity we do not study and sometimes do not notice, helping us become better educators and better communicators about science. It has long been recognized that memorable, deep learning takes place when people are actively engaged, collaborating, and applying their learning to their daily lives (Chickering and Gamson 1987). We aimed for this type of learning experience in our BioBlitz project for the students, faculty, and other affiliates involved.

Our Personal BioBlitz was novel in its duration, its participants, and its goals. It was longer than most BioBlitzes; instead of being a 24-hour intensive cataloging of the diversity at one site, our BioBlitz was a 76-day long, global effort in identifying species whenever and wherever we encountered them. Our BioBlitz was also unusual in that the participants were mostly students, faculty, staff, and affiliates of the Department in Ecology, Evolution, and Natural Resources, not representative of the broader citizenry usually targeted for BioBlitzes. Because of this demographic, our goals for the BioBlitz were somewhat unusual. Instead of focusing on the groups we were most interested in for the BioBlitz, our goals were to learn more broadly about biodiversity and make links between our research in ecology and evolution with our own and our students' daily experiences with the rest of biodiversity of an everyday life in a mostly urban area. We strongly believe that a Personal BioBlitz experience can be useful for everyone, not just biologists, because we all encounter a wide swath of biodiversity every day. A project

like this can lead people to better know and appreciate the species we see or use frequently, but may take for granted or know little about.

When we began this project, many of us had been involved in more traditional BioBlitzes, which have been gaining popularity since the late 1990s (Silvertown 2009) and traditionally serve one or several purposes. First, BioBlitzes may be used to generate a biodiversity inventory for a site and can provide a good baseline for species richness of many animals (Foster et al. 2013). Since our BioBlitz followed Rutgers students and faculty it gave a robust picture of on-campus diversity, as well as the additional species we have in our homes, offices, classrooms, and also see during fieldwork, vacations, and even commuting to work. A second function of a BioBlitz can be to discover new species (Harper et al. 2009), although the focus of our BioBlitz was to familiarize ourselves with the common species we encounter every day. A third and crucial function of most BioBlitzes is to engage and intrigue the general public about wild animals, plants, and conservation, which is particularly important now as our society becomes more disconnected with nature (Prévot-Julliard et al. 2014).

In addition to the above-mentioned purposes of a BioBlitz, our BioBlitz also served additional functions primarily related to our roles as current or future educators:

(1) *Provide insight into which organismal groups we tend to favor and which ones we tend to neglect*. As researchers and teachers of biological diversity and ecosystems, we should understand our (and our students') biases in terms of which species we notice and think are important. Our species lists for the Personal BioBlitz quantitatively demonstrate these biases. Understanding our own biases will help us take steps to build in more variety of organismal examples in our

classes so that we represent biodiversity and ecosystems more accurately in our teaching.

(2) *Recognize which species we interact with the most.* Since our BioBlitz occurred over several months, we were more cognizant of which species we had been seeing frequently, and which were new species to add to our lists. By thinking about which species we interact with most frequently we can recognize which species our students are also more likely to encounter and connect with.

(3) *Provide an incentive to learn how to identify a broad array of species.* Species identification is often difficult, but the BioBlitz motivated us to find, learn how to use, and evaluate online and offline identification tools that we and our students might use.

We designed our BioBlitz with three major premises in mind. First, interaction (collaborative or competitive) promotes learning. We designed this project to be both a competitive one (competitions can increase motivation in learning; Burguillo 2010) and a collaborative one (cooperation can also increase learning; Lord 2001). Additionally, a BioBlitz involves one of the classical ways to go about learning natural history - by going on a hike with someone more skilled in a target taxon. 'Naturalistic learning', or going outside and learning about biology by experiencing it in the landscape, is significantly underrepresented in today's undergraduate and graduate curricula, but can play a central role in the development of effective biologists (Randler 2008, Hayes 2009). Our second premise was that learning doesn't have to be tedious. One of the stumbling blocks that many people encounter when they are learning about a new taxonomic group is being able to see the differences between organisms. Many of these differences may seem

minute to a beginner, but become obvious once one has gained more experience with a particular group. Our BioBlitz allowed for people to list unfamiliar groups at family, order, or even phylum level. This way the bar for learning a group was lowered and any group, no matter how complex at the species level, could seem accessible. Our third premise was that a long BioBlitz allows participants to spend more time to become familiar with new groups of organisms. We wanted our BioBlitz to build up an appreciation of what was rare and what was common in our daily encounters. This is not possible with the 24-hour snapshot type of BioBlitz (O'Brien et al. 2011). Furthermore, the extended time period allowed us to change our behaviors in order to expand upon our daily settings, for example, explore new grocery stores, travel to new locations, take time to learn new identification tools, and facilitate collaborations.

We hope that our experiences can serve as a template for people and organizations to engage in Personal BioBlitz projects of their own. It blends together more traditional ideas of 'supermarket botany' (Burrows and Harper 2009) and backyard birding, with less common investigations like home entomology, potpourri and flower bouquet identification, grocery store zoology, metropolitan microbiology, sea shell picking, and pond phycology - endeavors that can help residents of our highly urbanized areas develop an appreciation for biodiversity and the importance of its conservation (Miller 2005). It is our hope that many other educators will use the Personal BioBlitz model as a hands-on tool for building knowledge and excitement about biodiversity at K-99 formal and informal education levels.

BIOBLITZ METHODS

General Details & Rules

Sampling for the BioBlitz was carried out from 1 March to 15 May 2014 and again from 1 March to 15 May 2015 (76 days each). Prior to the start of each sampling period a set of rules (table 1) were democratically agreed upon by the participants of the Journal Club in Evolution at Rutgers University (run by Lena Struwe and Siobain Duffy). The project was done as a voluntary, non-credit project during each participant's free time (outside of scheduled classes). Participants were allowed to sample 24-hours a day, 7 days a week, anywhere in the world. Living organisms were recorded only if they were seen or heard (not just smelled or with scat). Remnants of dead organisms (e.g., road kill, fossils, shells, seeds, fruits, dried leaves, feathers, antlers) were recorded as long as they allowed for the accurate identification of that species. Since one of the main objectives was to learn how to identify unlabeled biodiversity, any labeled species that were in zoological parks, pet stores, public aquariums, museums, botanical gardens, and other such places were not included in these BioBlitzes. In 2014, food species could be recorded so long as the recording participant ate them and these species were largely unaltered so that they could be identified through sight (i.e., whole nuts, seeds, fruits, vegetables were allowed, but antelope steak was not). Pets and cultivated plants were also allowed in 2014. However, in 2015, in order to follow the goals and vision of the iNaturalist website, all species had to be wild and naturally occurring.

Invitations to join the BioBlitzes were sent out through the Rutgers Evolution mailing list (150+ subscribers) and to all graduate students, faculty, and staff in the Graduate Program of Ecology and Evolution (200+) and Plant Biology (150+). In 2015, undergraduates in the Fundamentals of Evolution class (76) and majors in Ecology,

Evolution, and Natural Resources (120+) were invited to participate. Other people associated with Rutgers University either formally (i.e., undergraduate students, faculty and staff from other departments, and alumni) or informally (i.e., family and friends) were also invited to participate. All participants were allowed to get assistance with identifying species from any reputable source or person, such as co-workers, taxonomic experts, field guides, websites, and mobile apps. Collaboration with, and assistance by, fellow BioBlitz participants was especially encouraged.

Recording of Observations

During the 2014 BioBlitz each participant maintained an Excel spreadsheet list of observed species (or higher taxonomic ranks when species identification was not possible), dates, and localities throughout the sampling period. At the termination of the 2014 sampling period all lists were combined into a master list for subsequent analysis. In 2015, each participant recorded observations into a Personal BioBlitz Project created on iNaturalist (inaturalist.com), a website designed for documenting species observations across the world. The use of iNaturalist allowed for real-time record keeping of species, dates, and localities, as well as the inclusion of photographs, for all observations, and the auto-generation of personal species lists, both life lists and project-based. Another benefit of iNaturalist is that it allowed participants to get identification assistance and feedback on their observations from not only other BioBlitz participants, but also from all people part of the global iNaturalist community. At the end of the 2015 sampling period, iNaturalist was used to automatically compile a list of all the observations for the Personal BioBlitz Project, and this list was subsequently used for analysis.

Post-BioBlitz Surveys & Data Analysis

BioBlitz participants were asked to participate in a voluntary, anonymous survey of the experiences and effects of the BioBlitz on their personal knowledge, biodiversity education, and curiosity (IRB approval #E15-237). This post-BioBlitz survey was conducted in November 2014 and June 2015 for the 2014 BioBlitz and 2015 BioBlitz, respectively. The survey included open-ended questions (9 in 2014 and 11 in 2015) and 29 qualitative, multiple-choice questions (yes, no, or I don't know; table 2) for more specific data evaluation.

Basic statistics were performed using Microsoft Excel, Structured Query Language (SQL), and R Statistical Software. Specifically, the following statistics were calculated for each year: the number of participants and percentage of each type of participant (graduate students, faculty, undergraduate students, etc.), the number of observations and species within each taxon, the most commonly reported species, the number of participants contributing observations to each taxon, the percentage of observations from each country, and the number of observations per week. Furthermore, for the 2014 BioBlitz the percentages of edible species and New Jersey non-native species were calculated. The above-mentioned statistics were calculated using only observations that had a taxonomic status, date, and location. In 2014, some dates provided were ambiguous (for example “March 20-31, 2014”) and as such, these observations were excluded from the calculation of number of observations per day, but were included in other statistics.

BIOBLITZ FINDINGS

There were 30 participants in the 2014 BioBlitz and 78 participants in the 2015 BioBlitz. Participants were graduate students (63% in 2014; 28% in 2015), faculty (including retired faculty) and staff (30%; 20%), undergraduate students (0%; 41%) and others (family, friends, alumni; 7%; 12%) affiliated with the Graduate Programs of Ecology and Evolution, Microbiology, Philosophy, and Plant Biology at Rutgers University. Forty-two percent of participants who responded to the 2015 post-BioBlitz survey participated in both the 2014 and 2015 Personal BioBlitzes.

A total of 7270 observations from 30 participants were submitted in 2014 and a total of 11748 observations from 78 participants were submitted in 2015. Land plants (50% of total observations in 2014; 41% in 2015) were the most commonly reported group, followed by birds (26%; 37%), invertebrates (10%; 12%), fungi (4%; 3%), mammals (4%; 3%), fishes (2%; 1%), reptiles (2%; 1%), and amphibians (1%; 1%). Microscopic species were 'specialist' species not commonly reported and made up less than 1% of total observations in both years. In total, 3458 unique taxa (species or higher ranks) were seen, which decreased to 3057 in 2015 despite a higher number of participants. This was due to the exclusion of edible and other ethnobiological, non-wild, species in 2015.

The most reported species in 2014 were three different birds with 18 observations each (blue jay, *Cyanocitta cristata*; Northern cardinal, *Cardinalis cardinalis*; American robin, *Turdus migratorius*). A similar trend favoring birds as the most frequently observed species was seen in 2015 with Canada goose (*Branta canadensis*; 69 observations), American robin (*Turdus migratorius*; 66), and rock pigeon (*Columba livia*;

62) representing the three most reported species. Among plants, the *Asteraceae* family was observed most often in 2015 (315 observations; 106 species). The top three land plants reported in 2015 were the extremely common New Jersey species: dandelion (*Taraxacum officinale*; 35 observations), poison ivy (*Toxicodendron radicans*; 35), and red cedar (*Juniperus virginiana*; 32).

In 2014, 2779 species (80%) were only reported by one person. This number was reduced to 1655 in 2015 (54%; figure 1). While bird species were observed by a high number of people, we found land plants to contribute most to the number of unique species for both years (1614 species in 2014, 47%; 1322 species in 2015, 43%; figure 2). Birds contributed the second most unique species for both years (789, 23%; 908, 30%) followed by invertebrates (513, 15%; 453, 15%), fungi (205, 6%; 110; 4%), fishes (87, 3%; 86, 3%), mammals (83, 2%; 84, 3%), reptiles (63, 2%; 53, 2%), amphibians (32, 1%; 33, 1%), algae (21, 1%; 4, <1%), protists (37, 1%; 2, <1%), and bacteria (14, <1%; 2, <1%). In both years, more participants contributed to observations of birds (80% of participants reporting in 2014; 86% in 2015) and land plants (90%; 85%) than any other taxonomic group. Both years follow the same trend of a rapid decline in taxonomic group observations after birds and land plants, leading to the lowest percent of participants reporting protists (10%; 5%) and bacteria (13%; 4%; figure 3). A total of 91% of 2014 observations were identified to the species level, with a corresponding 99.9% in 2015. Species marked as having been eaten accounted for 8.7% of all taxa in 2014.

The majority of species were seen within New Jersey in both BioBlitzes (55% in 2014; 61% in 2015). In 2014, other localities included 15 other US states (15%) and 7 other countries: Sweden (20%), Sri Lanka (5%), Belize (4%), and the Bahamas, Ecuador,

France, and Canada (1%; figure 4a). In 2015, other localities included 6 other US states (20%) and 13 other countries: Costa Rica (8%), Guyana (6%), Israel (2%), and Sweden, Norway, Mexico, El Salvador, Brazil, Peru, Morocco, Jordan, Palestine, and China (3%; figure 4b). The number of species observations fluctuated across the weeks of the BioBlitz (figure 5). In both years, the most observations were recorded during the first week of the BioBlitz. In 2014, there was also a surge in observations during the week of spring break in mid-March (figure 5a) when many participants traveled out-of-state and/or out-of-country.

SURVEY FINDINGS

Of the 30 individuals who participated in the 2014 BioBlitz, 63% completed the survey. In 2015, 45% of the 78 participants completed the survey. The responses to the quantifiable questions are listed in table 2. The majority of survey participants (68% in 2014; 71% in 2015) reported species they didn't know existed before the BioBlitz. In both years a large majority (95%; 97%) used internet-based tools and resources to identify species and 63% and 68% sought out new species identification literature as part of their 2014 and 2015 efforts, respectively. In 2015, 58% of participants directly contacted a taxonomic expert for help with a specific taxonomic group.

The BioBlitz also promoted collaboration between BioBlitz participants (47%; 48%), as well as a competition, a feature that was enjoyed by 83% of participants in 2014 and 65% of participants in 2015. Approximately half (47%; 58%) of the participants focused primarily on a taxonomic group they already knew a lot about. In 2014, 58% of survey participants reported that they knew more plant species than bird species. In 2015

this number increased to 71%. Only 6% considered giving up during the 2014 BioBlitz, but this number rose sharply to 42% in 2015.

In 2014, a majority (68%) of participants listed at least some species they ate, and 42% specifically looked for species to eat in order to get them onto their lists. Thirty-seven percent of participants ate food items new to them just to get those species listed (thereby increasing the biodiversity level of their diets and experienced new food). In both years 50% of survey participants admitted they forgot to list humans as a species. Overall, participants found fewer species than they expected (47%; 67%). As a result of the BioBlitz, most participants reported improved knowledge of species identification (72%; 52%) and nearly all continued to learn new species after the BioBlitz concluded (95%; 97%). As a result, survey participants reported that joining the BioBlitz improved their knowledge of biodiversity in both 2014 (84%) and 2015 (74%). In both years, survey participants reported that they would join a Personal BioBlitz again (100%; 90%), and 84% (2014) and 77% (2015) of participants thought they would report more species the next time they participated in a BioBlitz.

Survey responses from both years suggest that participants found species identification difficult. One participant expressed this sentiment by saying "the BioBlitz… reminded me in a big way that species ID is not for the weak-willed." Another participant expressed frustration that commonly available ID tools were not detailed enough to provide species-level identification. We allowed listing of observations identified only as larger groups (family, genus, etc., but only once per group), which helped participants to learn a wider diversity of unfamiliar organisms, even if identification to the species level was difficult.

The long-term effects of this project have not been quantitatively tracked, but many participants suggested that they expected the BioBlitz to influence their future thoughts and behavior. Several participants reported that the project had changed the way they looked at biodiversity, including, "I am more aware of different materials and 'see them' in another perspective, for example, pine cones on Christmas decorations" and, "I notice things like plants that just sort of blended together before." One of the participants stated that this project even changed their way of learning about biodiversity: "I use many more digital and online tools to help identify species," a comment that also emphasized the importance of web-based identification for this project.

IMPLICATIONS FOR FUTURE BIOBLITZES

Justification for Personal BioBlitzes

There are many benefits to reversing our disconnect with wild species and natural systems through interaction with the natural world. These advantages include general health benefits (Maas et al. 2006) such as stress reduction (Stigsdotter et al. 2010). This style of project provides participants with an incentive to make this connection with both wild and domesticated species in their everyday lives. Our BioBlitz helped participants understand and appreciate biodiversity more than they did previously and this BioBlitz format can easily be implemented in a variety of settings.

In urban environments, wilderness (an area that has not been acted upon or significantly modified by humans) has become a novelty viewed as little more than an intriguing tourist destination (Nash 2001). Still, many continue to hold to the impression that interesting species are far away in rainforests, coral reefs, etc. and not in their

backyards, supermarkets, and parking lots. BioBlitzes remind us that we don't need to take trips to exotic destinations to find fascinating organisms: we have fungi growing on bathroom tiles, spider webs in conference rooms, weeds in asphalt cracks, and parasites in our urban streams. Our rediscovery of biodiversity is vitally important to efforts ranging from studies in conservation and invasion biology to help drive sustainable community management. As more people live in urban areas (UN 2014) and experience simplified media representations of 'nature' (Prévot-Julliard et al. 2014), BioBlitzes can help people realize that their connections to other species on the planet are more personal, numerous, and economically relevant than they previously thought.

Main Findings in the Personal BioBlitzes

Our Personal BioBlitz projects were able to accomplish their major goal of involving people in discovery and appreciation of biodiversity. A majority of the participants reported seeing species totally novel to them, improved knowledge of biodiversity, and responded favorably when asked if they would recommend participation to others. One participant wrote, "I realized what an amazing variety of species surround us. And what a variety of crops we have domesticated to eat." Another reported, "I honestly can't believe how much I learned." At the outset of the project, we were concerned that a long data collecting time would discourage participation (as opposed to 24-hour BioBlitzes). Instead, it appears that the long length strongly encouraged collaboration, planning visits to new places just to get more species on the list, and gave the time needed for identification of more difficult species.

Nearly all survey respondents used web-based tools for species identification at some period during the BioBlitz. These included online keys, as well as social communities (e.g., BugGuide, Facebook) where experts could contribute identifications. The internet has been recognized by educators as an important educational tool (Owston 1997), and recent work in Southeast Asia has highlighted the potential impact that a new generation of students using free web based tools could have on the study and preservation of biodiversity (Webb et al. 2010). The connection of beginners and experts has also been shown to contribute strongly to correct identification of species through internet taxon determining apps, such as iSpot, which employs a reputation based social media framework to encourage collaboration. This application has demonstrated a 57% increase in identification accuracy and the social media framework encourages many to generate identifications in as little as two hours (Silvertown et al. 2015). Our projects strongly emphasized the use of online resources and communities as tools for tracking and studying biodiversity. Similar to the aforementioned studies, we saw that in 2015 when we required the use of the web-based iNaturalist, which tracks observations of species by users around the world, identification of observations to species-level classification went from 91% in 2014 to 99.9% in 2015. This is likely due to the introduction of social media elements in iNaturalist, which participants noted to increase the accuracy of their identification, and with one survey responder stating that they "enjoyed the speed at which many of the identifications were confirmed."

We were also able to identify which species participants interacted with the most and which species are most easily observed by participants. Our pattern of taxon observation from both BioBlitzes is comparable to the pattern of global taxon

observations submitted to iNaturalist in 2014. BioBlitz participants paid the most attention to plants and birds and the least attention to microbiota. iNaturalist (2014) users also reported birds most often (34% of observations), plants next (28%), then invertebrates (21%), with microorganisms making up less than 1%. These observations of organismal groups do not strongly correspond to number of estimated species worldwide, but appear to be related to perceived charisma, body size, and organism mobility. For example, invertebrates (1305250 species; IUCN 2009), fishes (33100 species; Froese and Pauly 2015), and reptiles (10178 species; Uetz and Hošek 2015) are the three most speciose animal groups and yet all three fell behind birds in the number of observations and unique species record.

We did not find a 'plant blindness' (Allen 2003, Hershey 2002) problem. In fact, 90% of participants in 2014 and 85% of participants in 2015 recorded plants on their species list. While we may not have observed "plant blindness," we did find a "bird bias" with the blue jay, Northern cardinal, and American robin being the three top reported species in 2014 and Canada goose, Northern cardinal, and American robin in 2015. This bias might be perceived as recognition of visible or familiar species, but being familiar with an easily identified species did not necessarily increase its frequency of observation. Few observations for *Homo sapiens* were included in either year (12 in 2014; 28 in 2015) and accounted for less than the number of observations recorded for many species of birds. This brings us to a common phenomenon where our own species is not always considered part of nature (Vining et al. 2008). Our history and culture often reflects this perception that humans are something separate and not part of species diversity in ecological systems. For example, in urban ecology, humans are often not reported on

species lists for planned urban restoration projects (Steven Handel, Department of Ecology, Evolution, and Natural Resources, Rutgers University, New Brunswick, New Jersey, personal communication, 12 December 2014). To draw this to a point, we often take ourselves for granted and do not see ourselves as an integrated part of nature, thereby perpetuating the divide between civilization and natural systems, when in fact they are interwoven and inseparable.

The fewest reported species were fishes, amphibians, and microscopic species. The low number of observations for these species reflects a number of factors such as accessibility to technical equipment, climate, seasonality, and habitat. Organisms such as fish and other aquatic organisms are less accessible and some species likely have seasonal behavior preventing observation. Amphibians may have been largely neglected due to the relative difficulty in locating them. Observations of microscopic species could be inferred by the type of food eaten (for the 2014 BioBlitz) or, in the case of environmental samples, must be directly observed using a microscope. Limited experience identifying microscopic species and perceived technical obstacles likely contributed to the limited number of these types of organisms being observed.

Eating and Discovering Everyday Species

Allowing species from participants' diets in the 2014 BioBlitz encouraged a large percentage of survey respondents to look for new species to eat, indicating that the BioBlitz encouraged more curious eating. Of the species reported in 2014, 302 (8.7%) species were edible (from 240 genera), representing an impressive diversity of eaten organisms. When edible, cultivated species were no longer included in the BioBlitz, there

was a reduction in the number of plant observations from 50% of total observations in 2014 to 41% in 2015. The total number of singletons for plants also dropped dramatically between years, which we attribute to barring observations from participants' diets, landscaping plants, and houseplants. We believe that this decline in plant observations between years is because many of the edible, and/or cultivated species reported in 2014 were plants.

When we start to see biodiversity education as something focused on all species diversity, not just "wild" diversity, we will introduce a large group of people to taxonomic groups from all over the world in formal and informal educational settings. Promoting interaction with species otherwise ignored, such as edible species, weeds, and perceived pests, creates opportunity not only for personal development in the observer, but also for a stronger sense of belonging in one's biological community. We feel that professional biologists also need to stress this in their outreach efforts and make a strong commitment to local, personal biodiversity knowledge and curiosity.

Incorporation of a Personal BioBlitz into a Curriculum

BioBlitzes provide an active learning strategy for topics, such as organismal biology, biodiversity, taxonomy, species classification, ecology, conservation, and food diversity. There is inherent potential for projects like this one to be incorporated into regular curricula at various levels of education. Incorporating BioBlitzes into curricula increases student involvement and furthers development of practical scientific skills, such as species identification and biodiversity recognition. Short BioBlitzes have been carried out at middle school (Project Noah 2014), high school (Markman 2014) and college

levels (NYBG 2014). BioBlitzes can vary in duration, can be inclusive of all organisms, and can lack geographical constraints, as in the present study, or may be restricted to a particular taxonomic group of interest and a specific geographic location depending on the educational objectives. The low cost of this project means that it can be implemented even in schools with limited resources. Davies et al. (2012) suggest that students with low participation in other nature-related activities can benefit the most from projects like these. BioBlitzes like ours provide an active and collaborative opportunity for students to increase their awareness of biodiversity by participating in field research, carrying out literature searches, and organizing and analyzing data. The process of finding, observing, and identifying organisms develops critical thinking and analytical skills because it encourages students to interpret observed attributes of a species in order to draw a conclusion about its identity. BioBlitzes like ours also work to improve skills in team building and group collaboration.

Discovering new species is not just about achieving learning goals, but also about curiosity, seeing the world more clearly, and getting a sense of place. Even though learning scientific names is a turnoff for many students of biology, knowing species names is crucial for helping people connect their organism with the ocean of information available in literature and on the internet (since common names may not be unique or widely used; Stevens et al. 2014). Putting a name to a species we encounter in our everyday lives helps us understand where these organisms are in nature, their conservation status, their human uses, and also helps us develop an appreciation for other places and species on Earth. A Personal BioBlitz also allows participants to get a better sense of place when we notice how different lists become when we travel just one

building away, a few miles away, or a few hours away. Lastly, experiences with other organisms create memories, foster caring, and encourage the willingness to share memories, knowledge, and future experiences with others.

Feedback from the Personal BioBlitzes

Participants responded that they benefitted both from the competitive and collaborative aspects of this project. In a meta-analysis of 122 studies of educational outcomes of individual effort vs. collaborative vs. competitive interactions in learning settings, Johnson et al. (1981) found that collaboration promoted achievement (higher scores) more effectively than did individual work or competition, regardless of age group, subject, or assessment type. In our survey, 83% of respondents in 2014 and 65% in 2015 reported that they liked the competitive aspect of the BioBlitzes. When asked why they did not give up on the project in 2014, 37% of the responses mentioned the competitive aspect of the project as a key motivator, while only 26% mentioned the collaborative aspect of the competition as reason.

One participant reported that the most surprising thing about the BioBlitz was realizing "how many species I pass by without noticing" and "how easy it is to miss out on the diversity of our environment." Several participants reported that the 'not-noticing' had changed over the course of the BioBlitz: "I… 'saw' so many new things I never thought about before, from supermarket food to seashells to galls on plants" and "...I thought I was just going to upload stuff I knew. I learned hundreds of new species and recognize pretty much everything I see on a daily basis now." Another reported that one

positive experience of the activity was realizing “many objects around my everyday surrounding(s) are made of materials from living things.”

CONCLUSION

To summarize, the combination of a common and personal challenge and a focus on species discovery and observation over a longer time than a 24-hour BioBlitz had a long-lasting effect on participants' learning, excitement, and 'seeing' of biodiversity in their everyday life at work and at home. Our large dataset confirms the bias towards birds in species observation and biases against fishes, fungi, amphibians, and microbiota. The inclusion of non-wild species proved a success in that it opened participant's eyes to everyday biodiversity surrounding us wherever we are. We strongly encourage other educators to modify our methods and develop their own Personal BioBlitzes to increase the students and the public's awareness of species, nature, and science worldwide. The methodology works well with using online platforms and digital tools (as well as traditional species observation and identification), with participants spread out spatially and temporally across the world, as well as with well-circumscribed projects such as one undergraduate class and only reporting species on one campus.

SUPPLEMENTAL MATERIALS

All supplemental data from the 2014 and 2015 BioBlitzes can be accessed online at (http://dx.doi.org/doi:10.7282/T3R78H2G).

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Figure 1. Number of species within each major taxonomic group recorded by only a single BioBlitz participant during the 2014 (white) and 2015 (black) BioBlitzes. A large majority of species were recorded by only one person.

Figure 2. Number of species from each observed major taxonomic group. A total of 3458 unique species were reported during the 2014 BioBlitz (white). A total of 3057 unique species were reported during the 2015 BioBlitz (black). The most commonly reported groups during both years were land plants, birds, and invertebrates.

Figure 3. Number of BioBlitz participants who contributed to species counts of each major taxonomic group during 2014 (white) and 2015 (black). More people contributed to counts of land plants and birds than any other group. Fewer participants contributed to counts of invertebrates, mammals, fungi, amphibians, reptiles, fishes, algae, protists, and bacteria.

Figure 4. Geographic locations where species observations were made during the 2014 (a) and 2015 (b) BioBlitzes. Percentages represent the number of observations recorded at each location when compared to the total number of observations recorded. Most species observations were made within our own state, New Jersey, during 2014 and 2015.

Figure 5. Distribution of observations over the time span of the 2014 (a) and 2015 (b) BioBlitzes. In 2014 and 2015, the most observations were recorded during the first week

of the BioBlitz. In 2014, there was also a second peak in number of observations, which coincided with the week of Spring Break.

Table 1. Rules for our 2014 and 2015 BioBlitzes. All rules were democratically agreed upon by the members of the Journal Club in Evolution at Rutgers University.

BioBlitz Rules
1. Sampling can occur 24-hours a day, 7 days a week, anywhere in the world during the sampling period.
2. Songs or other sounds of birds, amphibians, and mammals can be counted only if the species can be identified through its sound.
3. Remnants of dead organisms (i.e., roadkill, fossils, shells, seeds, feathers, antlers, dried leaves) can be counted only if the species can be identified.
4. Food species from markets and stores can be counted only if eaten by the participant and if they are largely unaltered in their morphology (i.e., they are still identifiable to species). [i]
5. Pets and cultivated plants are allowed. [i]
6. Observations of labeled species in zoological parks, public aquariums, museums, botanical gardens, pet stores, and other such places are not allowed. All observations must come from unlabeled species.
7. Collaboration between participants and assistance from taxonomic experts is allowed.

[i] For the 2015 BioBlitz, food species, pets, and cultivated species were NOT allowed.

Table 2. Survey results (2014: n = 19 out of 30 participants; 2015: n = 35 out of 78 participants) of multiple-choice questions on the BioBlitz. Over 50% are marked in bold.

No.	Question: Range of Species	% Yes 2014/2015	% No 2014/2015	% Don't Know 2014/2015
1	I focused mostly on a group I knew a lot about.	48 / **58**	47 / 39	5; 3
2	I only listed species I already knew.	0 / 13	**100 / 87**	0 / 0
3	I listed at least some of the species I ate.	**68**	32	0
4	I looked for new species to eat to get them listed.	42	**58**	0
5	I forgot to list humans as a species.	39 / 48	**50 / 52**	11 / 0
6	I know more bird species than plant species.	37 / 26	**58 / 71**	5 / 3
7	I only listed live species I saw or heard.	32 / 48	**68 /** 48	0 / 3

No.	Question: The Process	% Yes 2014/2015	% No 2014/2015	% Don't Know 2014/2015
8	I ate things I had never eaten before to add to my list.	37	**63**	0
9	I sought out new identification literature.	**63 / 68**	32 / 32	5 / 0
10	I used the internet to find tools and information to key out some species.	**95 / 97**	0 / 3	5 / 0
11	I sought out help from experts for certain taxonomic groups.	42 / **58**	**58 /** 42	0 / 0
12	I sometimes collaborated with another participant in the BioBlitz.	47 / 48	**53 / 52**	0 / 0
13	I engaged my relatives in my search for species.	42 / 35	**58 / 65**	0 / 0

No.	Question: Personal Learning Outcomes	% Yes 2014/2015	% No 2014/2015	% Don't Know 2014/2015
15	I found more species than I expected.	42 / 20	47 / **67**	11 / 13
16	I saw species that I didn't even know existed before.	**68 / 71**	32 / 29	0 / 0
17	The BioBlitz encouraged me to visit new places I would not have gone to otherwise.	**53 /** 50	47 / 47	0 / 3
18	Being part of the BioBlitz helped my research.	18 / 29	**76 / 65**	6 / 6
19	I was surprised that the most commonly reported species were birds.	32 / 16	**58 / 77**	10 / 7
20	I learned a lot about species identification.	**72 / 52**	28 / 45	0 / 3

No.	Question: Appraisal & Outcomes	% Yes 2014/2015	% No 2014/2015	% Don't Know 2014/2015
22	I was considering giving up several times.	6 / 42	**89 / 55**	6 / 3
23	I have continued to list species after the BioBlitz.	47 / 29	**53 / 71**	0 / 0
24	I have continued to learn about new species.	**95 / 97**	5 / 3	0 / 0
25	The BioBlitz improved my biodiversity knowledge.	**84 / 74**	16 / 19	0 / 7
26	People that focused on plants had an advantage.	26 / 36	21 / 19	**53 / 45**
27	I liked that it also was a competition.	**83 / 65**	0 / 19	17 / 16
28	Would you join a Personal BioBlitz again?	**100 / 90**	0 / 7	0 / 3
29	I would recommend joining a BioBlitz to friends.	**100 / 94**	0 / 6	0 / 0
30	If you join again, do you think you will report more species?	**84 / 77**	0 / 7	16 / 16