Investigating Applications of a Large Citizen Science Dataset: The Wayne National Forest - Athens Unit BioBlitz

Darcy Higgins
Trimble, Ohio, USA
Prepared for
Project Dragonfly, Global Field Program,
Miami University

Abstract

This investigation attempted to discover realistic applications of a large citizen science dataset, the Wayne National Forest - Athens Unit BioBlitz. The BioBlitz was initiated without specific research questions or goals. I explored species richness data, geographic patterns, and youth participation as diverse pathways to uncover research questions and applications of the data. Species richness data uncovered specific taxons that were poor in data. It also indicated that a general BioBlitz push may not be an effective method for gathering information on threatened species, and more targeted citizen science efforts may be needed for these species. Geographically, a possible concentration of threatened species was identified north of Burr Oak Lake in the Wildcat Hollow region. Educationally, the BioBlitz stood out as an extremely promising tool for engaging students with the scientific process, and student-led experiments or action projects. However, student applications of the BioBlitz should not be pigeon-holed as just educational exercises. Students provided potentially actionable research questions and projects. The BioBlitz may be especially useful for hyperlocal science and conservation actions with schools and other community groups.

Introduction

Since the term was first coined for a National Park Service project in 1996 (Parker et al, 2018), the BioBlitz has caught on as a type of citizen science project. A BioBlitz is an effort to document every living species present in a certain place, within a certain amount of time. Proponents see them as an opportunity to engage and educate the public about biodiversity (Pollock et al., 2015; Hartry et al., 2017), while also providing data that otherwise would be too expensive, time-consuming, or localized to be collected by professional scientists (Bonney et al., 2014). With the increasing integration of the internet and smartphones into daily life, smartphone and web platforms for collecting citizen observations have become popular backbones of BioBlitzes and similar projects. The intuitive draw is to engage people where they already are -- using social networks on smartphones (Bonney et al, 2014).

Many enthusiastic evaluations of BioBlitz report positive outcomes in participant knowledge, engagement and attitudes (Pollock et al, 2015; Hartry et al, 2017). However, researchers attempting to put such data to use still hold concerns and doubts about its usefulness, particularly the data's noisiness and inconsistency (Bayraktarov et al, 2019; Parker et al, 2018). Platforms such as iNaturalist, an app in which users can upload observations of any species they encounter and have their identification checked by other users, are opportunistic rather than following typically accepted scientific sampling methods. iNaturalist is the data collection platform used by many BioBlitzes. At the root of the limitation of such a dataset, Bayraktarov et al (2019) argue, is that collection was undertaken without any particular research question in mind.

Propelled by just this kind of faith in the value of a BioBlitz, but lacking specific research goals, the non-profit Rural Action organized a 2017-2019 BioBlitz of the Athens Unit of Wayne National Forest (WNF). Rural Action is an organization that seeks to improve environmental, social, and economic conditions in southeast Ohio, and is the author's employer. The BioBlitz project has engaged at least 296 contributors, connected local scientific experts to the public, and become integrated into the curriculum of at least 4 local schools as of November 2019. Arguments for its success at growing a local community around conservation can easily be made. Yet, part of what makes participation compelling is the sense that one's observations matter, and are contributing to a greater effort. The data generated by the project has yet to be substantially applied to a purpose. Despite many good feelings about the project, and motivation from participants to "contribute to science," the scientific and action goals of the study have been murky.

This project takes a step towards bringing the WNF BioBlitz's potential to fruition by investigating the dataset and uncovering ongoing directions for the project. The broad question behind this IAP is: What useful questions can be asked using the WNF BioBlitz data, and what further opportunities for action inquiry should we pursue as the project continues?

To explore the possibilities of the dataset, I undertook three topics of inquiry, each with distinct questions, some comparative and some not:

Topic 1: Species Richness and Species of Interest

- *What species richness is documented in the WNF BioBlitz by taxon, and by general, threatened, or introduced status?*
- *How many species listed as of concern or invasive by the WNF administration were successfully documented in the BioBlitz dataset?*

This kind of descriptive data is what the iNaturalist platform most naturally facilitates. By exploring what species are present in this way, I hope that people experienced with the region's ecology may encounter surprises, insights, or questions.

In email exchanges between WNF and Rural Action staff, the WNF expressed that the most useful data to them is the presence of rare and endangered species, which informs their forest management plan revision process. As part of this process, WNF staff cross-referenced the WNF BioBlitz observations with their list of "must or should consider" at-risk species. However, the WNF staff stated that ultimately none of the species they were looking for were present in the BioBlitz data (K. Brooks, private communication, August 6 2019).

Because of the WNF's primary interest in protecting at-risk species, and combating invasive species, I focused on searching for patterns in the data on threatened and introduced species. By comparing BioBlitz data to the WNF-published lists, I sought insight into how successful the BioBlitz has been at collecting relevant and quality data.

Topic 2: Geographic Variation

- *Were more observations of general, threatened, and introduced species found in particular areas of the WNF-Athens Unit than other areas?*

Because all observations in the WNF BioBlitz are tied to geographic coordinates, there is the opportunity to identify potential biodiversity hotspots within the WNF, or, conversely, areas of degradation. Such information could potentially inform management decisions, or communication with or use by the public. The large number of amateur naturalists engaged by the BioBlitz could provide insight on locations not always monitored by WNF staff. Even a single sighting of a rare species can be valuable information to forest management.

Topic 3: Enlisting Student Perspectives in Geographic Comparisons, Generating Research Questions, and Generating Action Ideas

- *What differences in species richness by taxon and general, threatened, or introduced status exist between data collected at Logan Hocking Middle School, at Athens High School, and in the entire WNF-Athens Unit?*
- *What questions and action ideas do 5th grade citizen scientists see when engaging with the BioBlitz data?*

Keeping with the citizen-driven ethos of the BioBlitz, I aimed to bring students in the 5th grade science class at Logan Hocking Middle School into the process of inquiring into the BioBlitz data. The first two topics of my IAP reflect questions that I asked about the dataset. By taking the BioBlitz to the classroom, I am adding questions and action ideas that students formed about the dataset. I provided the initial structure of the iNaturalist/BioBlitz data collection process, as well as the initial comparative question (listed above). However, the questions and action ideas students subsequently generated out of that experience were their own.

School grounds typically have greater human disturbance than public lands, so comparing the ecological condition of the school land to the WNF could provide a useful reference to students for understanding the condition of their school's woods. By also comparing their school's land lab to another nearby school, they can gain insight into what is typical -- and what is possible -- for ecological health on school grounds.

Although Bayraktarov et al (2019) have doubts about the usefulness of data of the type collected by iNaturalist, they note that "Big unstructured data produced without a scientific question may be useful for the generation of hypotheses, but not necessarily for testing them." As I explored the dataset, I was interested not only in generating conclusive ecological research outcomes, but also in generating further hypotheses and topics of curiosity. Such questions, testable or not, might not be noticed without the BioBlitz. They can also inform the ongoing direction and future of the project, as well as local conservation outcomes. All would be concrete and valuable outcomes for the WNF BioBlitz project.

Methods

Data for topics 1 and 2 was downloaded from the WNF-Athens Unit BioBlitz project on iNaturalist.org on November 5, 2019. Only observations labeled "research-grade" by iNaturalist were included. Research-grade generally means that at least two users of the platform agreed on the identification of the observation. An observation was automatically included in the project if its coordinates were located within the proclamation boundaries of the WNF-Athens Unit, based on a map uploaded when the project was created in 2017.

Data used with 5th grade students for topic 3 was accessed on October 24, 2019 by students, directly through the iNaturalist website. All observations, regardless of whether they were "research-grade" or not were included. This is because the students' observations on their school grounds had just been added the previous day, and there was not sufficient time for their identifications to be verified by other users.

Topic 1: Species Richness and Species of Interest

- *What species richness is documented in the WNF BioBlitz by taxon, and by general, threatened, or introduced status?*

Species richness for all research-grade observations was tallied, and broken down by the taxons used by iNaturalist. Total species count and total observation count were included.

Additionally, the ratio of observations to species counts (# of observations / # of species) was calculated for each taxon. This was intended to provide a very rough indicator of how much effort it took for the presence of a new species to be confirmed in the BioBlitzes, and how thoroughly represented that taxon is in the dataset. An observation:species ratio close to 1 indicates that almost every time a participant adds an observation of that taxon, a new species is added to the BioBlitz dataset, making it more complete. A high observation:species ratio indicates diminishing return on participant effort: that, even with more observations by participants, they are unlikely to add new species to the dataset. Because iNaturalist collects observations opportunistically rather than systematically, its dataset can only be used to confirm presence of a species, not absence or abundance of a species. As such, contribution of previously unobserved species is an important factor in the dataset's quality.

The data was then filtered to display only species listed as "threatened" by iNaturalist, and only species listed as "introduced" by iNaturalist. The same species counts, observation counts, and observation:species ratio were tallied for these categories, and broken down by taxon.

- *How many species listed as of concern or invasive by the WNF administration were successfully documented in the BioBlitz dataset?*

Species of concern to the WNF included federally listed threatened and endangered species in the region, and the regional forester sensitive species list. A list of these species was downloaded from the WNF website (Wayne National Forest, "Threatened and Endangered Species," Accessed Sept. 11, 2019). The list was compared to the iNaturalist dataset to mark which species were present in the iNaturalist data. Number of observations of these species of concern to the WNF were tallied, and an observation: species ratio was calculated.

A list of invasive species considered "substantial threats" by the WNF was also downloaded from the WNF website (Wayne National Forest, "NNIS List," Accessed Sept. 11 2019). It was cross-referenced to the list of species labeled as "introduced" in the iNaturalist dataset. Because iNaturalist does not label species as "invasive," only introduced, the categories are not directly comparable; however, species listed as invasive should appear within the "introduced" data as well.

- *Were more observations of general, threatened, and introduced species found in particular areas of the WNF-Athens Unit than other areas?*

To identify concentrated areas of observations, the "find hot spots" analysis feature in ArcGIS was used to find clusters of high point count density along a fishnet grid. The "find hot spot" analysis was performed on the complete dataset, as well as only on observations of "threatened" species and only on observations of "introduced" species.

- *What differences in species richness by taxon and general, threatened, or introduced status exist between data collected at Logan Hocking Middle School, at Athens High School, and in the entire WNF-Athens Unit?*

Logan Hocking Middle School is technically outside of the WNF BioBlitz boundaries, so a separate iNaturalist project was created for their school BioBlitz (accessible here). 5th grade science students in Cort Forgrave's mixed-track science classes were the data collectors. The school grounds have a moderately large forested hill that is used as a land lab, and was the location of their BioBlitz. On day 1, students were able to go outside and make observations for the duration of a 42-minute class period, with a total of 6 classes participating. Students were supported by Rural Action Environmental Education AmeriCorps members.

Logan-Hocking students drew on data collected at the Athens High School BioBlitz (which was not part of this IAP). Data collected at Athens High School occurred over the course of two days in May 2019, and the entire sophomore class participated with support from experts, such as a water quality specialist, mycologist, or local birding enthusiast. Observations were included in an Athens High project page (accessible here). Because Athens High is within the WNF proclamation boundaries, all observations in the Athens High project were also automatically included in the WNF dataset.

Logan Hocking 5th graders analyzed their data the day after collecting observations. A chart was drawn on the board (see table 3). Students formed groups that were assigned one of the three BioBlitz locations, then explored the iNaturalist site to answer the questions in the chart.

The data collected by different class periods were combined into a single summary chart in the results section (table 3).

Before diving into data analysis, students were asked to share questions that had arisen from BioBlitzing the day before. After data analysis, students were asked to share any new questions that had emerged while looking at their data. Finally, students were asked to share any ideas they had for actions they could take based on what they learned (because of time limits, this only happened in four of the six classes). Some responses were written down in real time by a co-teacher, and others were written down as best as I could remember immediately following class, due to the limitations of being facilitator and researcher. The student-provided content will be discussed subjectively.

Results

1. Species Richness and Species of Interest

Across all taxons, a total of 7,864 research-grade observations were contributed to the WNF BioBlitz, documenting 2,450 species (Table 1). Insects were the best represented taxon, making up 56% (4,463) of all user observations and 59% (1,457) of total species documented. 88% (1,286) of the insect species and 70% (3,120) of insect observations were made by a single self-taught moth enthusiast, Diane Brooks, whose property is adjacent to the WNF. Gastropods were the least represented taxon, with only 9 observations and 7 species documented.

A total of 67 threatened species were recorded, with 220 observations (Table 1). The taxon with the most threatened species were birds, insects and plants. No threatened species at all were found among the amphibians, fish, arachnids, or fungi, and just one threatened gastropod.

94 introduced species were recorded, with 228 observations (Table 1). t.

Threatened species were found at about the same rate (3.3 observations/species) as general species were found (3.2 observations/species) (Table 1). However, surprisingly, new observations of introduced species were more likely than average to contribute new species to the BioBlitz, with 2.4 observations/species. This might be due to the bias of hobbyist naturalists to only upload observations of species considered "interesting," and to ignore common species. Presumably, introduced species are more common than threatened species, but participants contributed almost the same number observations of introduced as threatened species (228 vs. 220). Even though the common box turtle is listed as vulnerable globally, and thus considered "threatened" in iNaturalist's system, it was the fourth most-often observed species in the entire BioBlitz (observed 35 times).

Table 1. Species Richness by Taxon

	species	observations	observation:species ratio
All species	2450	7864	3.2
birds	88	206	2.3
amphibians	19	234	12.3
reptiles	17	114	6.7

mammals	25	141	5.6
plants	506	1906	3.8
fish	20	43	2.2
gastropods	7	9	1.3
arachnids	49	121	2.5
insects	1457	4463	3.1
fungi	236	568	2.4
Threatened species	67	220	3.3
birds	21	40	1.9
amphibians	0	0	0.0
reptiles	4	38	9.5
mammals	6	26	4.3
plants	12	38	3.2
fish	0	0	0.0
gastropods	1	2	2.0
arachnids	0	0	0.0
insects	23	76	3.3
fungi	0	0	0.0
Introduced species	94	228	2.4
birds	2	4	2.0
amphibians	0	0	0.0
reptiles	0	0	0.0
mammals	2	4	2.0
plants	74	187	2.5
fish	2	2	1.0
gastropods	1	1	1.0
arachnids	1	1	1.0
insects	10	27	2.7
fungi	0	0	0.0

The WNF lists 52 threatened species of concern. WNF BioBlitz participants found 6 of these (12% of the possible species of concern) (Table 2). These had a higher than average number of observations/species, which may be due to the high number of bobcat observations. If the bobcat observations are removed, then WNF-designated species of concern were found at about the same rate that other threatened species and general species were found, 3.2 observations/species..

The WNF lists 42 invasive species as substantial threats. BioBlitz participants documented just 16 of the 42 species considered invasive by the WNF, or 38%, despite the common occurrence of these species.

Table 2. Cross reference of species listed as threatened/endangered by the WNF with BioBlitz data.

Taxon	**Common Name**	**Scientific name**	**Number of observations in BioBlitz dataset**
Mammals	Bobcat	Lynx rufus	17
	Black Bear	Ursus americanus	0
	Indiana Bat	Myotis sodalis	0
Birds	Henslow's Sparrow	Ammodramus henslowii	0
	Cerulean Warbler	Dendroica cerulean	2
	Bald Eagle	Haliaeetus leucocephalus	1
Reptiles	Timber Rattlesnake	Crotalus horridus	0
Amphibians	Blanchard's Cricket frog	Acris crepitans blanchardi	0
	Eastern Hellbender	Cryptobranchus alleganiensis	0
	Four-toed Salamander	Hemidactylium scutatum	0
	Green Salamander	Aneides aeneus	0
	Mud Salamander	Pseudotriton montanus	0
Fishes	Western Lake Chubsucker	Erimyzon sucetta	0
	Eastern Sand Darter	Etheostoma pellucidum	0
	Ohio Lamprey	Ichthyomyzon bdellium	0
Mollusk	Round Hickorynut	Obovaria subrotunda	0
	Fanshell	Cyprogenia stegaria	0

	Lilliput	Simpsonaias ambigua	0
	Little Spectaclecase	Toxolasma parvus	0
	Pink Mucket Pearly Mussel	Lampsilis abrupta (=orbiculata)	0
	Salamander Mussel	Villosa lienosa	0
	Sheepnose	Plethobasus cyphyus	0
Insects	Green-faced Clubtail	Gomphus quadricolor	0
	Grizzled Skipper	Pyrgus wyandot	0
	Rapids Clubtail	Gomphus viridifrons	0
	American Burying Beetle	Nicrophorus americanus	0
Plants	Blue Scorpion-weed	Phacelia ranunculacea	0
	Butternut	Juglans cinerea	5
	Carolina Thistle	Cirsium carolinianum	0
	Dwarf Iris	Iris verna	0
	Eastern Featherbells	Stenanthium gramineum	0
	Greenish-white Sedge	Carex albolutescens	0
	Juniper Sedge	Carex juniperorum	0
	Large Marsh St. John’s Wort	Triadenum tubulosum	0
	Lined Sedge	Carex striatula	0
	Little-headed Nutrush	Scleria oligantha	0
	Maryland Butterfly Pea	Clitoria mariana	0
	Northern Monkshood	Aconitum noveboracense	0
	Pink Azalea	Rhododendron nudiflorum	0
	Rock Skullcap	Scutellaria saxatilis	1
	Running Buffalo Clover	Trifolium stoloniferum	0
	Small Whorled Pogonia	Isotria medeoloides	0
	Smooth Beardtongue	Penstemon laevigatus	0
	Sparse-lobed Grape Fern	Botrychium biternatum	0
	Striped Gentian	Gentiana villosa	0
	Summer Grape	Vitis cinerea	0
	Umbrella Magnolia	Magnolia tripetala	0

	Virginia Spiraea	Spiraea virginiana	0
	Whip Nut Rush	Scleria triglomerata	0
	Yellow Crownbeard	Verbesina occidentalis	0
	Yellow-fringe Orchid	Platanthera ciliaris	0
	Yellow Gentian	Gentiana alba	5
Number of Species on Wayne's list:		52	
Number of species found by BioBlitz:		6	
Number of observations of these species:		31	
Observations:species ratio:		5.17	

2. *Geographic Variation*

All general observations were concentrated in the area north and immediately west of Burr Oak Lake, an area which includes the Wildcat Hollow hiking trail (Fig. 1). ArcGIS calculated a confidence of 95% in these hotspots. Notably, moth enthusiast Diane Brooks' house is located in the area west of Burr Oak Lake.

Observations of threatened species were concentrated in a smaller area north of Burr Oak Lake and east of Corning, Ohio, with 95 - 99% confidence (Fig. 2). The threatened species hotspot is a smaller area within the general observation hotspot, at the northern edge (Fig. 3).

Observations of introduced species did not display any significant concentrations that could be considered hotspots.

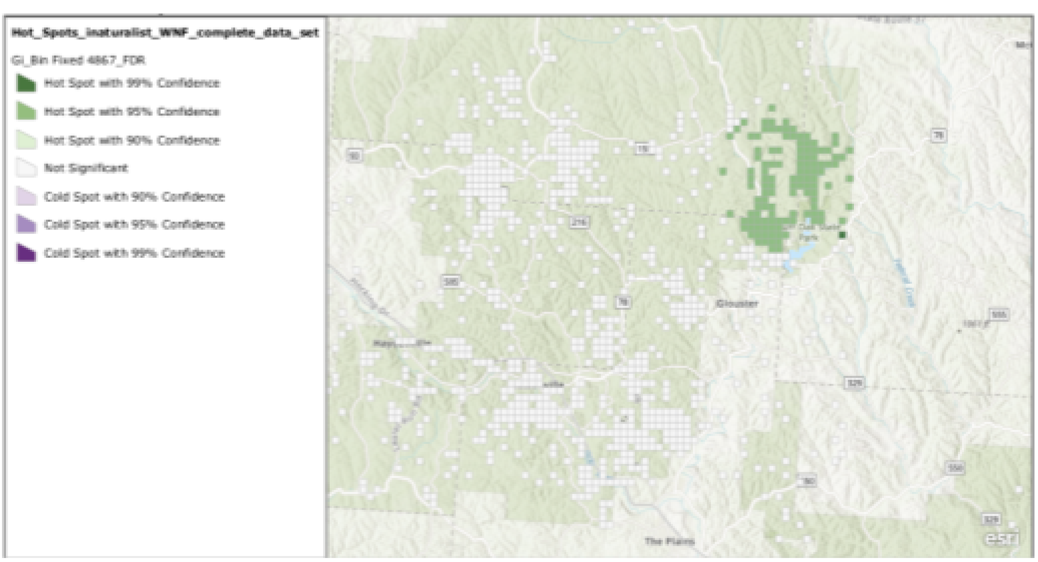

Figure 1. Geographic hotspots indicating concentration of observations across all categories.

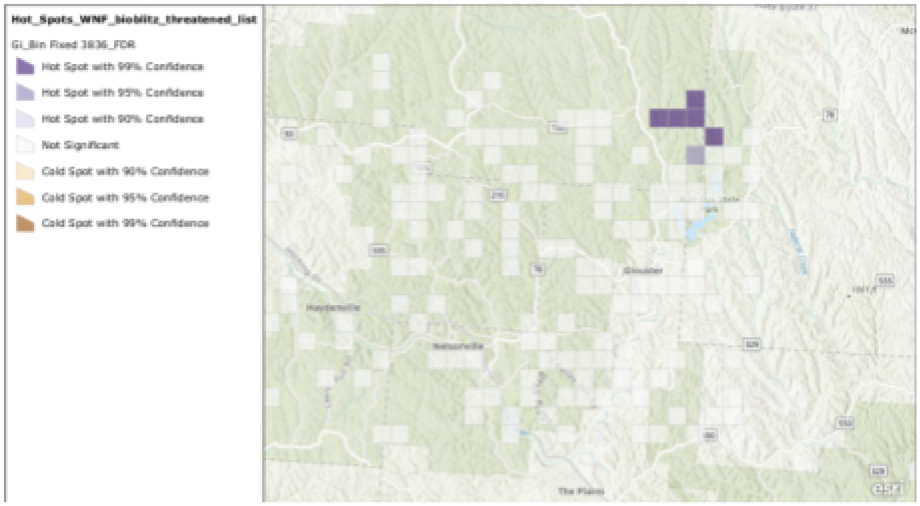

Figure 2. Geographic hotspots indicating concentration of observations of threatened species.

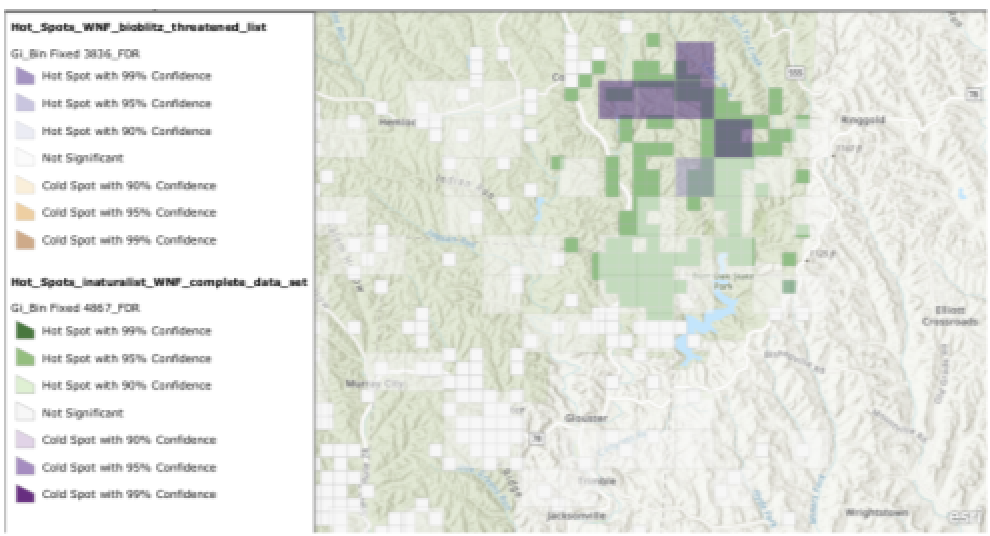

Figure 3. Overlap of hotspots of threatened species observations (purple) and general species observations (green) (close up of location).

3. *Student Perspectives in Geographic Comparisons, Generating Research Questions, and Generating Action Ideas*

The 5th grade classes at Logan-Hocking Middle School found that the data they collected on their school grounds contained many fewer species than the Athens High School BioBlitz: 68

species vs. 310. Results of the student inquiry can be seen in table 3. Species richness at both locations were dramatically smaller than on the WNF as a whole, which had 2,968 species (including non-research grade observations), but the schools had many fewer observations to draw from.

The only threatened species at Logan-Middle were white ash (many of which are in the process of dying) and one unverified observation of a blackjack oak. White ash also featured prominently in the threatened species found at Athens High School. The WNF BioBlitz as a whole contained a variety of threatened species beyond ash, including bobcats, gray foxes, and the hognose snake. Student participants displayed less bias for novel species over common species than the general public: the most observed species at both Athens High and Logan Hocking middle was the invasive multiflora rose, contrasted to the eastern pondhawk dragonfly for the general WNF BioBlitz. Students noted that their data collection did not do a good job of representing fish, protozoans, decomposers, pine trees, salamanders, or animals, although they believed it likely that some of those organisms were present on their land lab.

Table 3. BioBlitz data compared between Logan Hocking Middle, Athens High, and the WNF. Some misidentifications are included, reflecting student work.

	Logan Hocking Middle	**Athens High**	**WNF**
Number of observations	384	2226	11044
Number of species	68	310	2968
Most observed species	Multiflora rose	Multiflora rose	Eastern Pondhawk Luna Moth Eastern Newts
Were any threatened species found? (List species of interest)	White Ash Blackjack Oak	White Ash Green Ash Canadian Yew American Chestnut	Gray fox Bobcat Brown bat Hognose snake Eastern box turtle Slaty skimmer Green-striped darner

Were any introduced species found? (List species of interest)	Multiflora rose Autumn olive Common shiny woodlouse Japanese barberry	Ground ivy Apple White clover Japanese honeysuckle Garlic mustard	Black slug White poplar Japanese honeysuckle Western honeybee
What is likely present, but our methods failed to find?	Black bat Eastern Peacock Salamanders Fish Decomposers Pine trees Animals Dead Decomposers	Bobcat	Protozoans

Students had a number of questions that arose from the collection of data and others that arose after examining the data. They are detailed in table 4. Questions that emerged from the collection project tended to be about specific organisms, their traits, and their relationships to other factors around them. There were a greater quantity of these questions. Questions that emerged from the data analysis process mostly focused on bigger ecosystem influences, namely invasives and human development.

Table 4. Student Questions

Student Questions about BioBlitz Before Conducting Data Analysis
• Why is the honeysuckle sweet? • Do people use spicebush for anything? • Why is the skull there? [deer skull] • What type of rock was it? What kind of moss was on it? Why does moss grow on rocks? Why is moss fuzzy? How tall can moss grow? • How does poison ivy grow up trees? • Why does spicebush have that smell? • What does the salamander eat? • Are the red berries edible? • Why was the hole in the tree slimy? • Was the tree with the hole and wound dead or alive? • There were 4 bugs on a fungus. Why were they eating it?

● How could a log be soft and rotten on the outside but solid and hard on the inside?
Student Questions About BioBlitz After Conducting Data Analysis
● How did multiflora rose and other invasive species get here? ● Will Athens [nearby town] have fewer total species than Logan because it has more development and is growing? ● Why is the blackjack oak threatened? ● How can a vine climb the shagbark hickory if it's shaggy?

Student had a number of ideas for action based on their experience of collecting and analyzing the BioBlitz data, listed in table 5. Themes in the action ideas including improving or creating more habitat, fighting invasive species like the Emerald Ash Borer, and general environmental actions that they have likely encountered previously (such as installing sustainable energy, which was taught in a recent climate change unit, or picking up litter).

Table 5. Student Action Ideas

Student Action Ideas After Conducting BioBlitz Data Collection and Analysis
● Plant more trees [mentioned many times] ● Plant trees with seeds that spread around so that the forest spreads out further ● Plant good native plants that animals like to attract more species of plants and animals ● Recycle ● Get solar panels and plant trees where the electrical poles used to be ● Replace the dying ash trees with some other kind of tree ● Kill the emerald ash borer — get a spray, get a helicopter to spray it from ● Plant new ash trees ● Kill the invasive species [this idea prompted by back and forth with the instructor] ○ Then replace them with dandelions ● Add a pond because we didn't find any fish ● Pick up litter ("That's what clean up crew at recess is for, so you should come help")

Discussion

The taxon that was poorest represented by the data was the gastropods. With an observation:species ratio of 1.3, almost every observation added confirmed the presence of a new species in the BioBlitz. Birds, arachnids, fungi, fish and insects also had below average observation:species ratio. As such, concerted efforts to recruit more observations of these taxons seem the most likely to pay off with new data.

However, other platforms may simply be better for collecting data about certain taxons, namely birds and fish. iNaturalist requires pictures for observations to be confirmed, so it is challenging to contribute bird observations. Meanwhile, popular birding platforms like eBird and strong citizen science programs like the Christmas Bird Count already exist, and maybe be better sources of bird data. Similarly, state and watershed-level groups monitor fish populations already, and few hobbyist naturalists are engaging with fish observations on iNaturalist. To engage the public with fish ID would likely involve recruiting the very same professionals who already monitor fish to teach the public, or promoting a specialized citizen science stream monitoring program.

Threatened species seem to be discovered with the same amount of effort as general species. This implies that continuing to recruit more general observations to the BioBlitz might also correspond more discoveries of threatened species. However, this is only true up to a point. Taxons like reptiles and amphibians seemed to hit a ceiling on new threatened species discoveries once their observation:species ratios rose quite high, to 6.7 and 12.3. Only 4 threatened reptile and 0 amphibian species were found, even as more observations of the taxon were added and there are more such species in the region. For future BioBlitz direction, we can solicit more general observations of taxons with low observation:species ratios, like gastropods. But should explicitly seek out observations of specific species of interest for more saturated taxons, like amphibians.

Both the sensitive and invasive species lists published by the WNF had slim overlap with species found by the BioBlitz. As such, we may not be able to rely on general participation in the BioBlitz to locate these species. Specific targeted initiatives to solicit species of interest may be needed; for example, participants could be educated on a particular rare plant and encouraged to keep an eye out for it when they hike in appropriate habitats.

The power of a single motivated participant is clear in the robustness of the insect taxon; 59% of our species were insects, as compared to 35% of species observed worldwide on the entire iNaturalist site. This implies that the BioBlitz can be an effective way to harness the expertise and enthusiasm of non-professional naturalists by providing a platform and spotlight for their work. Diane Brooks' data on moths is almost certainly providing information that would not otherwise be collected. Finding and empowering similar passionate non-professionals could contribute significantly to the breadth of data available about the region. They would also make excellent partners for identifying and pursuing research questions.

If these gaps in dataset completeness can be addressed so that we have some confidence in its relative thoroughness, it may be possible to use the data to identify possible biodiversity hotspots. WNF and the region continue to host numerous resource extraction projects, including coal mining, hydraulic fracturing, and logging, so public awareness of which public lands are sensitive is valuable. The general observation hotspot map indicated only where more people have participated in the BioBlitz. However, there was a concentration of threatened species observations *within* that hotspot, it seems possible that the threatened species hotspot might actually reflect a location with greater diversity. The data is too unsystematic to confirm this, but it can identify locations as candidates for further diversity assessment. Furthermore, Rural Action can target areas that did not receive as dense participation as the general hotspot near Burr Oak for identification hikes and other events, to fill in the absence of information about those locations.

The results of Logan Hocking students' investigation highlighted the impact of invasive species on their school grounds. The dominance of multiflora rose and autumn olive appeared in the students' results and questions. Even the threatened species on the grounds, white ash, was threatened because of invasive ash borers. Although their questions and discoveries might be of little interest to the Wayne, they are genuinely good candidates for further scientific investigation by the school and community. The Wayne BioBlitz data was a useful comparison as a local ecological baseline, so that students could assess the ecological needs of their own school. Student action ideas for improving the ecological needs of their school were fairly realistic and on target, including expanding habitat, adding more species diversity, and replacing invasive species with natives.

From an educator's perspective, the BioBlitz was exceptional in getting students to tackle data collection, experimental design, hypothesis generation, and data analysis authentically. Students naturally saw the flaws in experimental design: they questioned whether their grounds truly had lower species richness than Athens, or if they simply had fewer observations; and they recognized that they had excluded almost every non-stationary organism because of their loud collection methods. They engaged in basic statistical tasks with curiosity and enthusiasm. With the scaffolding of the modeled comparative design, students began to ask questions about things like development and habitat loss, and invasive mitigation, with minimal direct instruction from the teacher. Their questions and ideas can easily be turned not just to future lesson topics tailored to student interests, but also to authentic co-authored investigations or service projects. As such, the BioBlitz data has potential as a tool for small-level community projects, like school improvements, to generate hypotheses, questions and actions based on scientific data. Such projects might not be of interest to scientific journals, but it does provide a practical application of the data.

Action

Two weeks after the BioBlitz, we returned to Logan Hocking to plant ginseng, an at-risk and culturally important herb, with the students. Because of the BioBlitz background, students were able to understand the significance of returning a native plant to the understory and increasing diversity in their woods. This was an adult-determined activity, but reflected some of students' action ideas. Hopefully, through continued partnership with the teacher, Cort Forgrave, we can engage students in designing and carrying out further actions and/or investigations reflecting student ideas. The encouraging first results also provide a model for incorporating this educational program at more schools. Although previous schools like Athens High have participated extensively in data collection, no other school has followed up with data analysis. Incorporating data analysis follow ups at more schools will not only create potential investigations and service projects for the schools; the students are also a viable pool of further questions that could direct the future of the BioBlitz citizen science project.

As Rural Action considers the future of the project, the least complete taxons should be prioritized for outreach and attention. For example, although the fungi taxon still needs further attention, it has improved significantly since we began sponsoring monthly fungi hikes led by an Ohio University mycologist. Similar programs could be initiated for arachnids, gastropods, and insects (which are so numerous that the taxon would still benefit from more observations, despite the above average number of observations).

By contrast, saturated taxons that are still missing information on species of interest would benefit from targeting those specific species. For example, if it is unknown whether the at-risk striped gentian is still present in the WNF, BioBlitz participants could be solicited to make a special effort to be alert for it. If information on invasive species locations is desired, a separate promotion to solicit invasive observations would be necessary. In these cases, these would constitute almost their own citizen science initiatives, but could benefit from building off the existing platform and community.

Supporting and retaining star participants should be a priority, and looking for avenues for their data to be used. A number of experts, professional or not, have participated in the project on high school BioBlitz days. These relationships could be built on to create more pillars of the project. We should build relationships that follow up on research and outreach potential of their work.

The ideas generated in this IAP remain diverse, and not all of these directions can be taken at once. The next step is to share these possible directions with other stakeholders in the project, including co-workers and the WNF. Through discussion, we can determine which of these questions are realistic directions, and which are of greatest interest to pursue.

Conclusion

This investigation attempted to discover realistic applications of a large citizen science bioblitz dataset, which had been collected without specific research questions. I explored species richness data, geographic patterns, and youth participation as diverse pathways to uncover research questions and applications of the data.

The species richness data indicated that several taxons in the dataset need more observations, which might strengthen the usefulness of the data from the perspective of a large institution like the National Forest. It also indicated that a general BioBlitz push may not be an effective way to gather much information on threatened species. Species-specific, targeted citizen science projects might need to be designed if rare species is of primary interest.

Geographically, a possible concentration of threatened species was identified north of Burr Oak Lake in the Wildcat Hollow region. This may warrant further investigation by stakeholders such as Rural Action and WNF staff. Other possible hotspot locations might exist, but to locate them, a systematic effort to increase BioBlitz participation in under-observed areas would be necessary.

One of the areas with most promise for application of the BioBlitz is with schools, and potentially other small community groups. Educationally, the tool was excellent for engaging students in many stages of the scientific process, as well as mastering ecological concepts. However, the tool extended beyond the educational. Questions about the specific conditions and needs of participants' school grounds were generated, and realistic and meaningful action ideas were suggested. Both could be acted on with tangible results at participating schools. Future directions for the BioBlitz should prioritize follow through on these highly localized investigations and actions, and be sure to communicate to grant-funders and project partners the ways in which this is genuine science, not just an educational exercise.

Literature Cited

Bayraktarov, E., Ehmke, G., O'Connor, J., Burns, E.L., Nguyen, H.A., McRae, L., Possingham, H.P. and Lindenmayer, D.B. (2019) Do Big Unstructured Biodiversity Data Mean More Knowledge? *Frontiers in Ecology and Evolution.* 6:239. doi: 10.3389/fevo.2018.00239

Clemens, J. & Zipf, A. (2017) .Completeness of citizen science biodiversity data from a volunteered geographic information perspective. *Geo-spatial Information Science*, 20:1, 3-13, DOI: 10.1080/10095020.2017.1288424

Bonney, R., Shirk, J.L., Phillips, T.B., Wiggins, A., Ballard, H.L., Miller-Rushing, A.J., and Parrish, J.K. (2014). Next Steps for Citizen Science. *Science,* 1436-1437.

Hartry, A., Collins, M., Pande, A., Nava,R. & Waller, K (2017). Evaluation of 2016 National Park BioBlitzes. Prepared for the National Geographic Society by the Lawrence Hall of Science, University of California, Berkeley. Retrieved from https://www.informalscience.org/evaluation-2016-centennial-bioblitzes-outcomes-participants-and-national-parks

Parker, S. S., Pauly, G. B., Moore, J. , Fraga, N. S., Knapp, J. J., Principe, Z. , Brown, B. V., Randall, J. M., Cohen, B. S. and Wake, T. A. (2018), Adapting the bioblitz to meet conservation needs. *Conservation Biology*, 32, 1007-1019. doi:10.1111/cobi.13103

Pollock, N.B., Howe, N., Irizarry, I., Lorusso, N., Kruger, A., Himmler, K., and Struwe, L. (2015). Personal BioBlitz: A New Way to Encourage Biodiversity Discovery and Knowledge in K–99 Education and Outreach. *BioScience*, 65:12, 1154–1164, https://doi.org/10.1093/biosci/biv140

Wayne National Forest. N.D. Non-native Invasive Species on the Wayne National Forest. Retrieved September 11, 2019 from https://www.fs.usda.gov/detailfull/wayne/landmanagement/resourcemanagement/?cid=fsm9_006105&width=full.