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Citizen Science Contributions to Address Biodiversity Loss and Conservation Planning in a Rapidly Developing Region

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Abstract: Biodiversity data support conservation research and inform conservation decisions addressing the wicked problem of biodiversity loss. However, these data often need processing and compilation before use, which exceed the time availability of professional scientists. Nevertheless, scientists can recruit, train, and support a network of citizen scientists to prepare these data using online platforms. Here, we describe three citizen science projects sponsored by the Arkansas Natural Heritage Commission to transcribe and georeference historic herbarium specimens and document current biodiversity through iNaturalist for two highly biodiverse and rapidly developing counties in Northwest Arkansas, USA. Citizen science-generated data will be used in a county natural heritage inventory (CNHI) report, including a comprehensive list of taxa tied to voucher specimens and records for rare plant populations. Since the CNHI project started in 2018, citizen scientists have transcribed 8855 and georeferenced 2636 specimen records. From iNaturalist observations, 125 rare plant populations of 39 taxa have been documented. This CNHI report will determine the most critical taxa, habitats, and sites for conservation action in the region and will inform conservation stakeholders at the local, state, and federal levels as they engage in land acquisition, ecological restoration, natural resource management, planning of growth and development, and environmental review/regulation.

Keywords: community science; transcription; Notes from Nature; georeferencing; iNaturalist; element occurrence record; county natural heritage inventory; biodiversity inventory; rare plant taxa

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1. Introduction

The rapid loss of biodiversity represents a wicked problem in conservation and demands innovative ways to quickly document populations of rare taxa and areas with high conservation value to provide protection before populations are lost and taxa become extinct [1]. Biodiversity is being lost before it is described [2], and an estimated 39% of plant taxa alone are at risk of extinction [3], with only 10% of all plant taxa assessed using the IUCN Red List guidelines [4]. To tackle the grand challenges for plant conservation in the 21st century, Gillson et al. [5] recommend several areas to focus efforts, including fundamental information on plant diversity, distribution, and abundance, particularly for taxa of conservation concern; the need for curation of biodiversity data to be accessible and useful; and fostering connections among plants, people, and places to increase local knowledge and reconnect people with nature.

Compilation of biodiversity data supports conservation action to address the problem of rapid biodiversity loss, and both historic and current biodiversity records provide valuable spatial and temporal information to those applying resources to land acquisition, conservation planning, ecological restoration, environmental review/regulation, and other on-the-ground conservation actions [1]. Specifically, biodiversity data guide the application of conservation resources (funding, labor, and education/outreach efforts) toward the highest priority sites, species, and ecosystems [2]. Historic biodiversity records include specimens in natural history collections. Herbarium specimens document changes in the distribution of taxa over time [6], including extant and extirpated population locations and information about why taxa have been lost [7], such as specific habitat changes or expansion of invasive taxa [8,9]. Current biodiversity records include observations on iNaturalist that provide information about extant populations [10,11], current distribution data [12], and early detection of invasive taxa [13]. However, both historic and current biodiversity records require resource-intensive processing to make the data standardized and useful [14]. The information on herbarium specimen labels must be transcribed into a standardized database and the locality georeferenced for historic biodiversity records to be useful in modern botanical research [15,16]. An obstacle for using herbarium specimens as biodiversity data for conservation action is a lack of digitized records of sufficient quantity and quality for taxa and region of interest [14], and observations from iNaturalist need to be verified for correct identification and location and determined to be wild [17,18].

Alternatives to using these historic and current biodiversity records include massive on-the-ground inventory efforts that are not possible with limited resources available [17]. Conservation research can be time-intensive and costly, and populations of rare taxa and areas with high conservation value need to be protected proactively to decrease the risk of extinction [19]. Understanding biodiversity loss requires decades of fine-scale data over a regional extent [20], and collecting long-term monitoring data needed to evaluate conservation status demands time in excess of that available for professional scientists and resource managers to accomplish [2,17,21]. However, time estimates to digitize all natural history collections, including animal collections, range from decades [22] to a millennium [23], and digitization efforts lack staff and funding to expedite the process, representing a major impediment to providing these critical data to conservation decision makers and on-the-ground practitioners [24,25]. While professional scientists cannot quickly process the historic and generate the current biodiversity records needed for conservation evaluation themselves, they can support and train a global network of citizen scientists to accomplish this task [10,26], and results of a 2018 survey showed that 52% of the U.S. and all Canadian natural heritage programs reported use of citizen science data [17].

Citizen science has made significant contributions to both conservation and biodiversity research, and citizen science projects can be successfully supported by interdisciplinary teams from academia, agencies, and natural history museums using digital technology [27]. In 388 projects sampled in the first quantitative review of citizen science collected data for biodiversity research, participation of 1.3 million volunteers was estimated to contribute $2.5 billion USD in kind [21], a large amount of labor for citizen science projects at a relatively low cost of the project organizer's time [28]. Natural history museums provide settings to engage citizen science through education and conservation science [26], and these museums have worked with amateur naturalists for hundreds of years to document biodiversity [29,30], providing support in sharing knowledge about identification and field techniques, access to equipment and reference collections, and curation to accession specimens collected [31]. Citizen scientists acquire scientific knowledge, such as taxon identification by documenting observations on iNaturalist [10] while contributing to biodiversity research. Local citizen scientists also benefit from giving back to their community [32], and local knowledge improves the quality of transcription and georeferencing in digitizing historic biodiversity records [33,34]. Citizen science is a viable tool to increase biodiversity data availability [11,35].

Regional biodiversity studies require processing thousands of historic and current biodiversity records. Several online platforms allow citizen scientists to participate in processing these data into publicly available, standardized databases. Here, we describe building and supporting a citizen science network to increase the accessibility of verified biodiversity records from two highly biodiverse and rapidly developing counties in Northwest Arkansas, USA (Benton and Washington) [36] through three online platforms: (1) transcribing herbarium specimens on Notes from Nature, (2) georeferencing herbarium specimen localities using Collaborative Georeferencing (CoGe), and (3) documenting current taxon presence and distribution through iNaturalist, with a focus on finding previously unknown populations of tracked taxa, populations of indicator taxa, and county records. These citizen scientist-generated data will be compiled and integrated into statewide biodiversity data sets used to identify the most critical areas for biodiversity conservation and prioritize these sites for conservation investment and ecological management.

2. Materials and Methods

2.1. Study Area

The regional area of focus consists of two counties in Northwest Arkansas, USA: Benton and Washington (Figure 1A). Benton County is the northwestern-most county in Arkansas and includes approximately 2290 km^2 entirely in the Ozark Highlands (Level III) Ecoregion [37]. Washington County is south of Benton County and includes approximately 2465 km^2, with 1074 km^2 in the northern and western portion of the county in the Ozark Highlands Ecoregion and 1391 km^2 in the southern and western portion of the county in Boston Mountains Ecoregion [37]. In terms of the number of taxa documented by herbarium specimen vouchers, Benton and Washington Counties are the fourth and second most floristically diverse counties in Arkansas, respectively [38]. Benton County has 1239 vascular plant taxa documented, and Washington County has 1444 taxa documented.

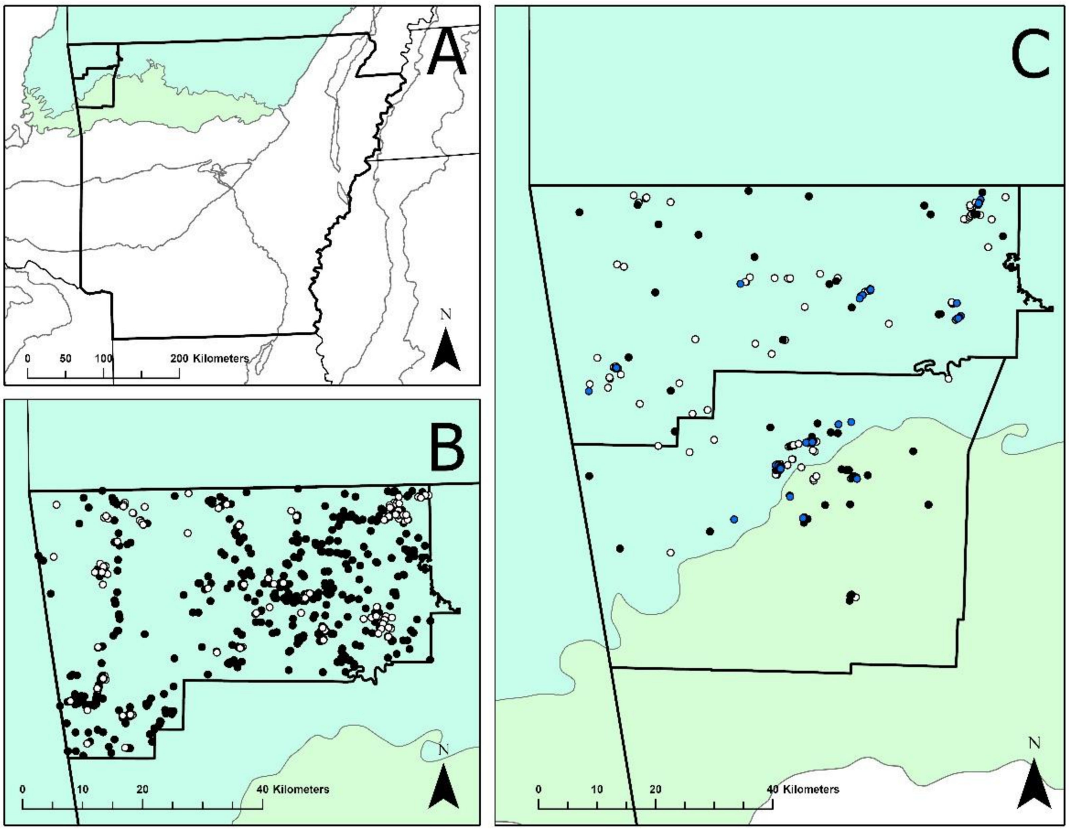

Figure 1. Maps of (**A**) the study area in Northwest Arkansas, USA, and its ecoregion context of the Ozark Highlands (north—blue) and Boston Mountains (south—green) [37], (**B**) the Benton County georeferenced points with point data from before the project in white (557 points, 17%) and generated through the project in black (2636 points, 83%), and (**C**) element occurrence records (EORs) of tracked taxa identified on iNaturalist from Benton and Washington Counties with pre-existing EORs in white, updated EORs from iNaturalist observations in blue, and new EORs from iNaturalist observations in black.

Benton and Washington Counties are the second and third most populous counties in Arkansas, respectively. Northwest Arkansas (NWA) has experienced significant population growth resulting in the urban transformation of the landscape [36] in a recent and relatively short period of time. From 1980–2015, the population of NWA counties increased at a greater rate than the population of Arkansas, which increased by 30%. The population of Benton County tripled, and the population of Washington County doubled [36]. The resulting landcover conversion to urban areas from 1995 to 2015 increased over 150% in NWA [36].

2.2. County Natural Heritage Inventory

The Arkansas Natural Heritage Commission (ANHC) in Little Rock, AR, USA started conducting its first County Natural Heritage Inventories (CNHIs) in 2018 based in part on methodologies used by the Pennsylvania Natural Heritage Program [39]. CNHIs collect and compile important biological and ecological information concerning rare taxa and habitats, exemplary natural communities, and intact landscapes. CNHI data come from many sources (including remote sensing, field surveys, scientific literature, and museum records), and these data are included in the heritage program database, which curates data on the occurrence and status of taxa and natural communities of conservation concern [40] CNHIs are concerned primarily with understanding and summarizing biodiversity, and the final CNHI report will consist of five sections: (1) summary of natural history and ecology, (2) comprehensive taxon-level biodiversity summary, (3) elements of conservation concern, (4) threats to biodiversity, and (5) sites of high conservation value.

Biodiversity records will augment the second through fifth sections of the CNHI report. A single record of every taxon will be included in the comprehensive taxon-level biodiversity summary for each county; these records will be prioritized first by herbarium specimen vouchers and then by iNaturalist (https://www.inaturalist.org accessed on 25 February 2021) observations vetted by ANHC botanists. For elements of conservation concern, every digitized herbarium specimen record and current biodiversity record will be included for element occurrence records (EORs) and indicator taxa. Of particular interest are records that will create new or update existing EORs, which are records of the occurrence of a taxon of state conservation concern with, at a minimum, data on taxon, location, and date, but ideally with additional data on population size and condition, area occupied, habitat type and quality, associated taxa, threats, and other information [17,39]. Indicator taxa are described as: (1) having a strong affinity to a single uncommon to rare habitat type; and/or (2) being indicative of intact, stable natural communities where ecological processes are allowed to proceed [41]. Documentation of new invasive taxa or the spread of invasive taxa through the study area will identify current and future threats to biodiversity and help inform ecological management priorities. Unprotected areas with elements of conservation concern will be prioritized as sites with high conservation value. The goal of these CNHIs is to identify, based on the best available data and science, areas critical for biodiversity conservation (specifically areas containing rare habitats, high-quality natural communities, intact landscapes, and populations of rare species) and to prioritize these sites for protection and management. This includes the identification of specific threats, both established and emerging, such as invasive species and impacts from climate change.

2.3. Citizen Science Online Platforms

2.3.1. Notes from Nature—Plants of Arkansas Project

Notes from Nature is a citizen science project on the Zooniverse platform that supports the transcription of natural history collection specimen labels into a standardized database [42]. The Notes from Nature—Plants of Arkansas project provides citizen scientists a platform to transcribe herbarium specimen label data from museum specimens of plants housed in Arkansas herbaria or collected from Arkansas with the goal of building a research-quality database [43]. The Plants of Arkansas project partnered with the ANHC to transcribe herbarium specimens collected from Benton and Washington Counties from seven Arkansas herbaria: Arkansas State University Herbarium (STAR), Arkansas Tech University Herbarium (APCR), Henderson State University Herbarium (HEND), Hendrix College Herbarium (HXC), University of Arkansas Herbarium (UARK), University of Arkansas at Monticello Herbarium (UAM), and University of Central Arkansas Herbarium (UCAC), and six herbaria outside of Arkansas: Austin Peay State University Herbarium (APSC), Florida State University, Robert K. Godfrey Herbarium (FSU), Harvard University Herbaria (H), University of Georgia Herbarium (GA), University of North Carolina at Chapel Hill Herbarium (NCU), and University of Tennessee Vascular Herbarium (TENN). All these collections publish specimen records in Symbiota: twelve of these collections publish on the Southeast Regional Network of Expertise in Collections (SERNEC) [44] while H publishes in the Consortium of Northeastern Herbaria. While the Notes from Nature—Plants of Arkansas project requires no formal training, Soteropoulos organizes transcription events and engages with the citizen online, as detailed in [43].

2.3.2. Collaborative Georeferencing—Arkansas Vascular Flora Project

Eight Arkansas herbaria (Arkansas Natural Heritage Commission Herbarium (ANHC), STAR, APCR, HEND, HXC, UARK, UAM, and UCAC) use the GEOLocate (https://www.geo-locate.org/web/WebComGeoref.aspx) Collaborative Georeferencing Client (CoGe) to georeference all Arkansas-held specimens from a county of interest concurrently through the Arkansas Vascular Flora project. The CoGe platform (https://coge.geo-locate.org/) links duplicate specimens, potential duplicate collection events and suggests similar localities based on place names for users to georeference groups of specimens efficiently.

Due to the complexity of the georeferencing tools, citizen scientists were required to attend a two-hour group training event followed by an hour and a half one-on-one training session; all sessions were hosted virtually. During the group training, Soteropoulos discussed the concepts and purpose of georeferencing and then demonstrated real-time georeferencing of localities. By not having prepared localities, the thought process to find localities was shared and repeated through a series of examples. The one-on-one training sessions allowed new georeferencers an opportunity to go through the georeferencing process with expert assistance to gain familiarity with the GEOLocate tools. Citizen scientists were provided with a standard operating procedure for reference (Appendix A). Soteropoulos provided virtual "office hours" for question-and-answer periods with CoGe as needed.

The Arkansas Vascular Flora project launched specimens from Benton County on 6 May 2020, and specimens from Washington County on 19 November 2020. The first group training session to georeference specimens from Benton County was 11 May 2020, and the second group training session to georeference specimens from Washington County was 1 December 2020. Since all specimens from Benton County have been georeferenced, only data from Benton County were analyzed.

2.3.3. iNaturalist

iNaturalist connects people to nature through making biodiversity observations (https://www.inaturalist.org) that include locality information, date and time of observation, and photographs of the organism. Several projects in Northwest Arkansas collect observations of interest to the CNHI project, including: Biodiversity of Benton County, Biodiversity of Washington County, ANHC Natural Areas Inventory, Northwest Arkansas Master Naturalists Observations, and Biodiversity of Northwest Arkansas Land Trust Preserves.

2.4. Analysis

2.4.1. Notes from Nature—Plants of Arkansas Project

The unreconciled transcripts of five completed Notes from Nature expeditions containing specimens from Benton and Washington Counties were imported to R version 3.5.1 [45]. Grouping methods follow those described in detail in Soteropoulos and Marsico [43]. Briefly, users were grouped into 7 groups based on affiliation (Table 1).

Table 1. User groups organized by the total number of transcriptions produced by each group (as in [43]). Unassigned includes usernames that were not recognized to belong to a particular group. User groups included Mega-contributor for global users completing > 10,000 transcriptions on the Plants of Arkansas project, Team for members of the Plants of Arkansas core team who are the lead researchers and project moderators, CAMN for users in Central Arkansas Master Naturalists organization (engaged January 2019), NWAMN for users in Northwest Arkansas Master Naturalists organization (trained January 2020), combined Arkansas Master Naturalist groups (Northeast Arkansas and Diamond Lakes) with Arkansas Native Plant Society (ANPS) members, and students from A-State.

User Group	Number of Users	Total Transcriptions	Percent of Total	Transcriptions per User	Total Days	Mean Days per User
CAMN	9	10851	40.48	1206	277	30.78
Mega-contributor	4	9157	34.16	2289	139	34.75
NWAMN	39	2516	9.39	65	190	4.87
Unassigned	48	1418	5.29	30	141	2.94
Not logged in	Unknown	1316	4.91	N/A	N/A	N/A
Team	3	921	3.44	307	118	39.33
A-State	48	535	2.00	11	50	1.04
Other AMN and ANPS	6	92	0.34	15	15	2.50

2.4.2. Collaborative Georeferencing—Arkansas Vascular Flora Project

All records from Benton County, Arkansas, were exported from eight Arkansas herbaria on SERNEC [44]. Records without spatial identities and with or without georeferencing attempts were filtered out of the dataset; thus, only records with spatial identities remained. Maps were created using ArcGIS Pro [46]. Using the Arkansas County Boundaries polygon [47]), the records were clipped within the boundary of the polygon, removing any georeferenced points outside of the county boundaries. The United States Environmental Protection Agency in Washington, DC, USA [37] supplied the state boundaries and Level III Ecoregions.

2.4.3. iNaturalist

All iNaturalist plant observations from Benton and Washington Counties in Arkansas were downloaded on 27 February 2021. Observations with identifications matching the ANHC Heritage tracking list were vetted by Witsell, new populations of tracked taxa of interest compiled, and observations of known populations compiled to update EORs in the Arkansas Natural Heritage Database, the official database maintained by the ANHC of specific occurrence records of elements of state conservation concern, including rare taxa and rare natural communities [48]. Vascular plant observations with identifications matching indicator taxa [41] were also vetted and compiled by Witsell. Observations with identifications matching the Arkansas Flora [38] that would be new county records, i.e., the first documentation of a taxon from the county, were also vetted. The vetting process included confirmation of (1) accurate identification, (2) wildness (not cultivated), and (3) accuracy of coordinates. Records of target taxa with the localities obscured were flagged, and the observers were contacted to request accurate coordinates. Occurrence data on the taxa of conservation concern will be added to the Arkansas Natural Heritage Database for use in research, environmental review, and conservation planning [17,40,48]. Only records that could be positively identified were incorporated into the database. Records that were based on cultivated specimens were marked as cultivated in iNaturalist, so they could be excluded from future analyses. Observers were contacted for clarification regarding records for which wildness was unclear. Observations made by ANHC staff or paid contractors during the CNHI project period were not counted as contributions by citizen scientists. A map of new/updated records of taxa of conservation concern from iNaturalist was plotted with existing (known) EORS of the same taxa from the ANHC Natural Heritage Database using ArcGIS Pro [46,48].

3. Results

3.1. Notes from Nature—Plants of Arkansas Project

The Plants of Arkansas project had active expeditions from Benton and Washington Counties from 20 December 2018 to 4 April 2019 and 2 January 2020 to 29 March 2020. The five completed expeditions, including Benton and Washington Counties, resulted in 26,806 transcriptions and 8855 completed specimen records uploaded to Symbiota (Figure 2, Table S1). Of the 157 registered users who contributed, 109 (69%) were assigned to a user group (Table S2). Assigned usernames contributed 24,072 transcriptions (90%) while unassigned usernames contributed 1418 transcriptions (~5%), and users who transcribed without signing in completed 1316 transcriptions (~5%).

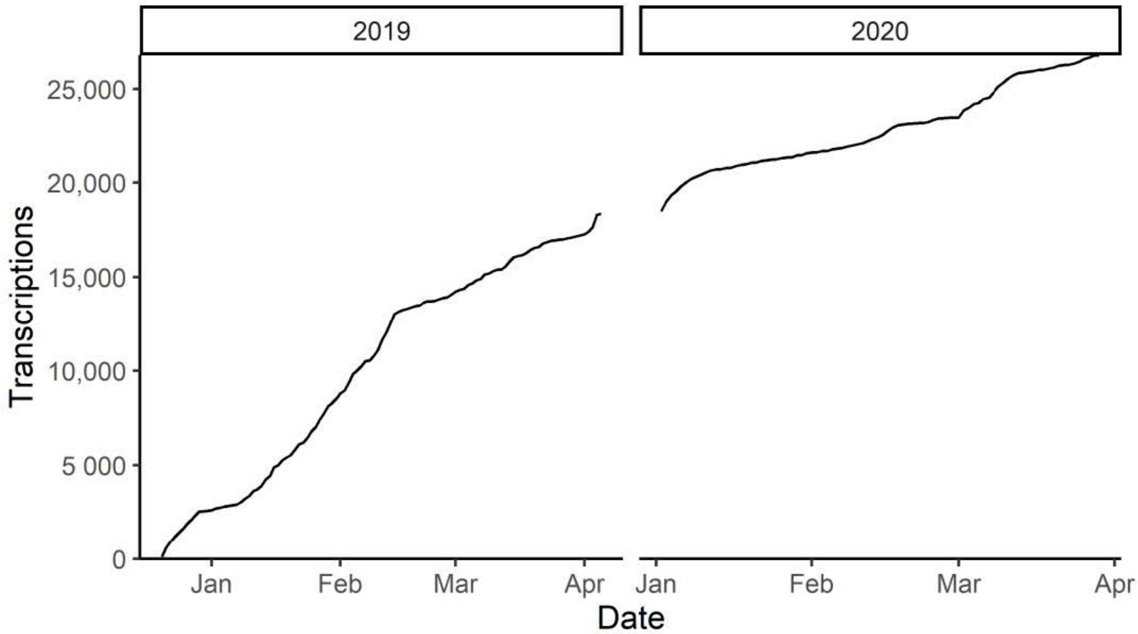

Figure 2. The cumulative transcriptions of five completed expeditions with specimens from Benton and Washington Counties, Arkansas, USA, in the Plants of Arkansas project on Notes from Nature.

The top user group, Central Arkansas Master Naturalists (CAMN), contributed 10,851 transcriptions (41%, Table 1 and Table S2). Mega-contributors transcribed 9157 specimens (34%), followed by Northwest Arkansas Master Naturalist members contributing 2516 transcriptions (9.4%, Table 1 and Table S2). Students from Arkansas State University contributed 535 transcriptions (2%), with 14 Plant Systematics students completing a class assignment and at least 34 additional students transcribing during a WeDigBio event. In total, 14,007 transcriptions (52%) are attributed to 104 Arkansan transcribers.

3.2. Collaborative Georeferencing—Arkansas Vascular Flora Project

The Collaborative Georeferencing (CoGe) effort included only specimens from eight Arkansas herbaria (Table S3). Thirteen individuals georeferenced Benton County specimens on the CoGe project between 6 May 2020 and 11 February 2021. Of the 3284 records from Benton County, 3177 records have geocoordinates. The 107 records without geocoordinates include 18 records with insufficient locality descriptions and 89 records with the county as the only location information. Only 557 records had geocoordinates prior to this CoGe project (17%; Figure 1B). Through the CoGe project, 2636 records were georeferenced (83%; Figure 1B), though 10 of those points were accurately georeferenced outside of the Benton County boundary and thus removed. Citizen scientists (n = 9) georeferenced 1688 records (64%) with the remaining 948 records (36%) georeferenced by ANHC staff (n = 4), including 158 by the collectors (n = 2) and the other 790 while developing the georeferencing protocol or during group training events.

3.3. iNaturalist

The iNaturalist effort included 4267 observations identified by Witsell for potential inclusion in the CNHI, 2198 observations from Benton County, and 2069 observations from Washington County; observations were made between 29 May 2005 and 27 February 2021 (Table S4). Of these records, 99 records for Benton County were changed to captive/cultivated, and 186 records for Washington County were changed to captive/cultivated. Benton County observations were submitted by 345 users (24 users submitted only captive/cultivated observations), and Washington County observations were submitted by 456 users (74 users submitted only captive/cultivated observations). Across both counties, there were 722 unique observers.

Observations from iNaturalist will be included in the Heritage Database, the Arkansas Flora Database (the database maintained by the ANHC that includes the official documented checklist of the flora of Arkansas), and the CNHI report. For taxa of conservation concern in Benton County, 57 records of 23 taxa, which includes 26 new records (46%) of 14 taxa and 31 updated records (54%) of 14 taxa, from 21 users will be incorporated into EORs (Table 2, Figure 1C, Table S4). For Washington County, 68 records of 23 taxa, which includes 35 new records (51%) of 16 taxa and 33 updated records (49%) of 14 taxa, from 15 users will be incorporated into EORs (Table 2, Figure 1C, Table S4). New EORs fill spatial data gaps scattered throughout each county (Figure 1C). County record observations from iNaturalist increase the total number of taxa known from Benton County from 1239 to 1324 and from Washington County from 1444 to 1497 (Table 2). The county record observations include 13 invasive taxa (16%) from Benton County and 11 invasive taxa (21%) from Washington County; in total, 20 new invasive taxa were added to the county taxon lists.

Table 2. Citizen scientist contributions to the County Natural Heritage Inventory (CNHI) report for Benton and Washington Counties, Arkansas, USA. Population records of tracked taxa will be incorporated into the Natural Heritage Database, which includes creating records for new populations and updating records of previously known populations [48]. Indicator taxa have a high conservation value and indicate high-quality habitats. County records are taxa not previously known from a county [38].

Type of Record	Benton			Washington		
	Count	Taxa	Citizen Scientists	Count	Taxa	Citizen Scientists
New population records of tracked taxa	26	14	14	35	16	9
Updated population records of tracked taxa	31	14	11	33	14	12
Populations of indicator taxa	20	10	13	24	10	11
County records	85 [1]	85 [1] (14) [2]	47	53 [1]	53 [1] (11) [2]	19

[1] Since a county record is the first documentation of a taxon from the county, the count of county records equals the number of taxa. [2] The number in parentheses indicates the number of new invasive taxa documented in the CNHI.

3.4. Citizen Science Contributions to the CNHI Report

The CNHI report consists of five sections, and citizen scientists' efforts described here contribute to four of these (Figure 3). Historic biodiversity records are transcribed by citizen scientists on Notes from Nature before being georeferenced in CoGe. The transcription of herbarium specimens alone informs the comprehensive taxon-level biodiversity summary (an annotated county taxon list) and provides additional information about the habitats, locations, and dates of collection for the elements of conservation concern. By georeferencing these records, we gained the geospatial data to identify sites of high conservation value as areas with rare and/or indicator taxa occurrences and also identify current or pending threats to biodiversity. The current biodiversity records (iNaturalist observations) inform the same four report sections with the addition of recent observations of invasive taxa as county records to know new threats to biodiversity.

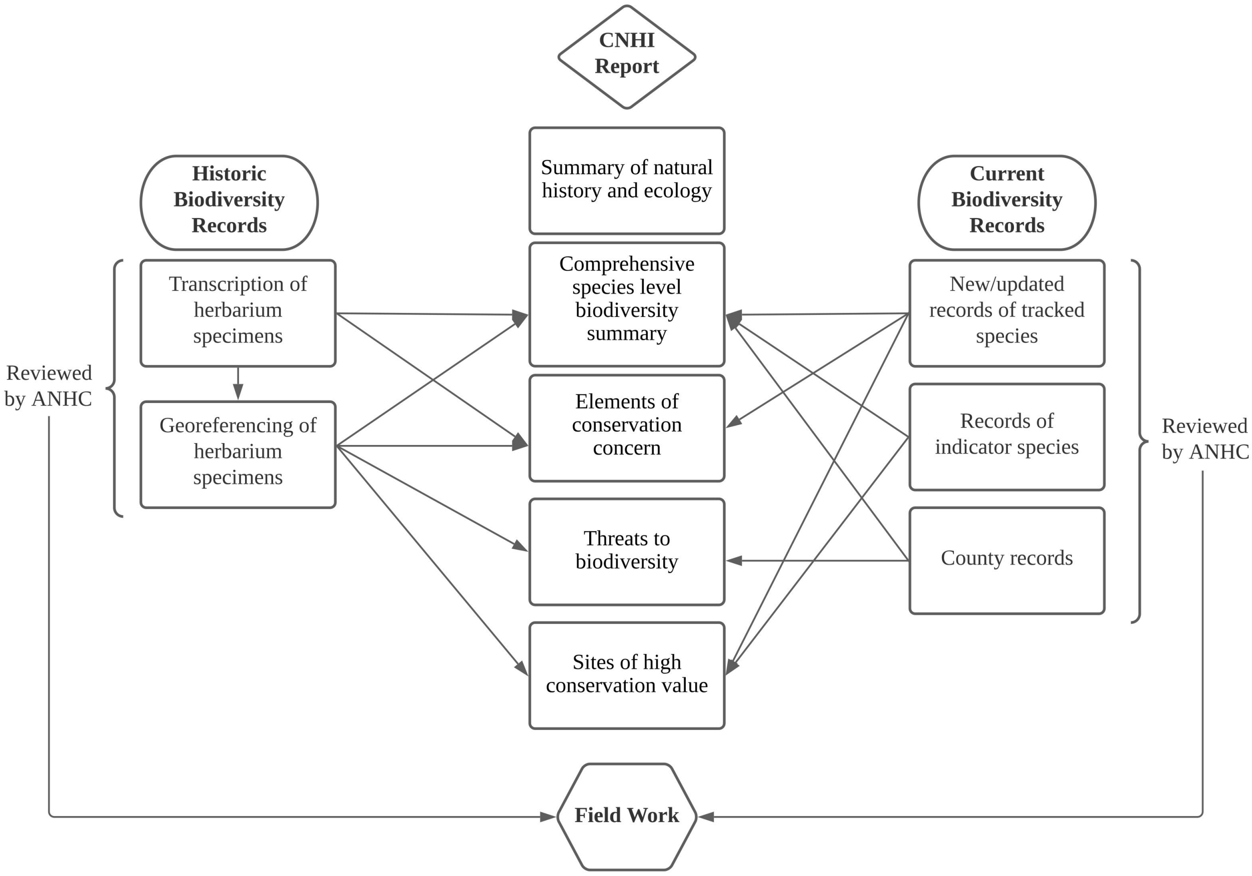

Figure 3. Citizen scientists' contributions to historic and current biodiversity records and where they impact the County Natural Heritage Inventory (CHNHI) report. For historic biodiversity records, citizen scientists transcribe herbarium specimen records into standardized databases. The locality information from the record is then georeferenced. For current biodiversity records, iNaturalist observations are reviewed by ANHC staff to identify new records of tracked taxa or update known records of tracked taxa, where tracked taxa are those of conservation concern. Records of indicator taxa, which have high conservation value, and county records are also verified.

4. Discussion

In this paper, we have documented the extensive contributions of citizen scientists in processing and creating biodiversity data. To our knowledge, we have provided the first example of connecting a citizen scientist data processing of digitized collections project to conservation outcomes [26]. The goal of incorporating citizen scientist data into heritage program data sets is to be used in and thus improve conservation decision making [17]. The CNHI report and the compiled, verified biodiversity records that inform it will be used specifically to identify and prioritize ecosystems and sites for protection and management. The report will be available publicly, and citizen scientists will be provided with a link to the report, demonstrations of accessing the data generated through online portals, and a copy of this open-access journal article as a testament to their contributions [31]. The ANHC is dedicated to serving constituents of Arkansas and interested citizen scientists by sharing knowledge, teaching the public about open-access resources, and learning from their local knowledge [32]. With a long history of providing data to and working with a variety of conservation partners, the ANHC will leverage conservation action in Northwest Arkansas with the CNHI report.

With a small staff and limited resources, the Arkansas Natural Heritage Commission (ANHC) enlisted citizen scientists to process existing and gather new biodiversity data to support the first-ever CNHI [41] for the state of Arkansas in the rapidly developing region of Benton and Washington Counties (Figure 1A) [36]. The CNHIs address several elements of the grand challenges for plant conservation this century posed by Gillson et al. [5]. Specifically, the three citizen science projects (Notes from Nature, Collaborative Georeferencing (CoGe), and iNaturalist) used in compiling these data addressed the challenges of creating fundamental information for plant diversity and distribution and for data to be accessible while fostering connections of plants, people, and places [5]. All included citizen science biodiversity records were curated to fit the plant conservation goal of meeting biodiversity data quality and accessibility standards [5], overcoming the usability barrier of inconsistent citizen science data across projects by vetting all data used in the CNHI project [18].

Citizen scientist transcription through the Notes from Nature platform has proven success on the Plants of Arkansas project through proper support and communication, including response to questions, hosting in-person events, and valuing citizen science contributions [31,43]. The large percentage of transcriptions (90%) assigned to a user group shows the dedication of known citizen scientists to the project (Table 1 and Table S2). Recruiting local citizen scientists through three training workshops in Northwest Arkansas added local knowledge, enhancing the transcription effort through awareness of changes in place names, knowledge of confusing names, or accepted spelling variations, such as the spelling of Lake Wedington near the town of Weddington (e.g., see Subject 38876584), which can otherwise require extensive time and research to learn [33]. This effort made available 8,855 specimen records from 13 herbaria, 67% of all Symbiota records from Benton and Washington Counties [44].

To our knowledge, the only study comparing expert-generated geocoordinates and citizen science-generated geocoordinates, using students as a proxy, discussed differences in the georeferencing process used by each group [34]. Citizen scientists tended to measure the distance from a named place to a location of interest as the crow flies as opposed to measuring distance along a road, as performed by the experts, who also found typos in directions, such as east instead of west [34]. For the CoGe Arkansas Vascular Flora project, Soteropoulos emphasized the process used by expert georeferencers through real-time georeferencing in a two-hour group training session, reinforced the process through one-on-one training sessions, reiterated the process to answer questions during office hours, and provided citizen scientists with a standard operating procedure to connect the process steps with the CoGe tools (Appendix A). Resources found by the citizen scientists, such as bridgehunter.com to find historic and low water bridges, were shared with the georeferencing group to increase the tools at their disposal.

Several localities georeferenced through this project emphasized the benefits of citizen scientists' local knowledge and proximity to the area being georeferenced [33]. A major landscape change in Northwest Arkansas occurred when the U.S. Army Corps of Engineers constructed Beaver Dam across the White River in 1960–1966, creating a 12,800 ha reservoir called Beaver Lake [49]. Many places on herbarium specimens collected prior to the dam's construction are now under the reservoir, such as Monte Ne, which occurred on 307 specimens georeferenced (Table S3). The construction of Beaver Lake also changed the county boundary as recently as 2010 [50], and the absence of points from the eastern appendage in Benton County may be due to the specimen records being attributed to Carroll County (Figure 1B). Having citizen scientists attuned to the areas associated with the specimen localities allowed for higher accuracy of lesser-known or vague locality descriptions.

Collection biases documented in voucher specimens, such as the bias against collecting difficult groups such as graminoids or the bias toward collecting close to infrastructure [51], can be mirrored in opportunistic citizen science projects such as iNaturalist, limiting the detection of difficult to identify, hard-to-photograph, or non-charismatic taxa and the documentation of taxa from remote or difficult to access sites [17]. Consequently, some showy taxa of conservation concern, such as *Asclepias incarnata* ssp. *incarnata*, may be over-represented in our results while others are likely under-represented, such as sedges and grasses. Location biases in where citizen scientists tend to make observations, such as at existing parks and nature preserves, along the counties' extensive public trail systems, and near easy access points concentrate observations and tend to avoid more remote areas and the more intact natural communities often found in them [17]. These biases can inflate the number of cultivated observations from plantings along roads, trails, and other public rights-of-way that might not be identifiable as cultivated observations by the observer. Many observations of native, and even some rare taxa, were cultivated in home gardens, city parks, and botanical gardens but not marked as such by observers; in total, 285 observations (7%) were changed to captive/cultivated. Location biases also concentrate observations on already protected public land where the flora is relatively well documented. For example, the spatial distribution of records of rare taxa (Figure 1C) indicates a paucity of records in the more rugged areas of southern Washington County in the Boston Mountains ecoregion. However, despite these biases, citizen scientist observations of taxa of conservation concern filled large gaps in known distribution for some taxa (Figure 1C). Additionally, iNaturalist has the potential to both identify and track the localities and distributions of invasive species. This was exemplified through the identification of 20 new invasive taxa reported in Benton and Washington Counties (Table 2). Concurrently, 44 populations of 20 indicator taxa were identified by 23 citizen scientists for both Benton and Washington Counties (Table 2). Through this example alone, it is established that the use of citizen scientist-generated data is important for the future protection of high-quality habitats with concentrations of rare and indicator taxa, which might otherwise be overlooked or unidentified.

5. Conclusions

Natural Heritage Program data represent a major tool in focusing conservation resources to address the wicked problem of rapid biodiversity loss and drive conservation decisions in the region in five major ways: (1) guiding the acquisition of significant conservation lands, (2) providing data for use in environmental review and impact analysis, (3) identifying certain sites within protected lands to avoid when developing infrastructure improvements and recreational amenities (such as roads, parking areas, and mountain bike trails), (4) prioritizing specific sites, on both public and private lands, for restoration and management actions such as removal of invasive species and prescribed burning, and (5) providing locations for known at-risk populations of species of conservation concern that may need mitigating measures such as conservation transplantation for ex-situ conservation. Local agencies and organizations working in Benton and Washington Counties who use ANHC data for these purposes include Arkansas State Parks, the Arkansas Game and Fish Commission, the Arkansas Department of Transportation (ARDOT), the U.S. Forest Service, the U.S. Fish and Wildlife Service, the National Park Service (NPS), several municipalities (including Bentonville, Fayetteville, and Rogers), The Nature Conservancy, the Northwest Arkansas Land Trust, the Fayetteville Natural Heritage Association, the Watershed Conservation Resource Center, the Northwest Arkansas Open Space Planning Committee, and the Walton Family Foundation. An example of mitigation through conservation transplantation is the location of two rare taxa, *Apocynum* × *floribundum* and *Asclepias incarnata* ssp. *incarnata*, found by citizen scientists in a road right-of-way on private property that would have been impacted by mowing. Members of the ANHC, ArDOT, UARK, and local citizen scientists worked together to relocate the plants to a protected location. An outcome from the inventory of managed conservation lands occurred when a citizen scientist identified the second known location in the state of a tracked taxon, *Acer nigrum*, at Pea Ridge National Military Park. The ANHC then reported the occurrence to the NPS for inclusion in their rare species management plan. With two more years (2021–2022) of surveys in the CNHI project period, citizen scientists will continue collecting and processing biodiversity data. The ANHC will use these data to identify the highest priority sites for conservation in the counties and will work with the conservation community to conserve, protect, and manage these sites in the future.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/d13060255/s1, Table S1: A list of specimen barcodes transcribed through Notes from Nature. Table S2: Transcriptions by Notes from Nature username with the assigned group. Table S3: Benton County specimen barcodes from Arkansas herbaria with georeferencer and if georeferenced through CoGe. Table S4: Reviewed biodiversity occurrence data from iNaturalist (observations with coordinates redacted for threatened and endangered taxa as well as those at risk for poaching that are listed as Sensitive Species of Arkansas on SERNEC; data are available through the Arkansas Heritage Database upon request: https://www.arkansasheritage.com/arkansas-natural-heritage/programs/data-requests).

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Informed Consent Statement: Informed consent was obtained from all subjects in the study through the privacy policies of the citizen science platforms.

Data Availability Statement: Publicly available datasets were analyzed in this study. Biodiversity occurrence data published by: Arkansas Natural Heritage Commission Herbarium, Arkansas State University Herbarium, Arkansas Tech University Herbarium, Henderson State University Herbarium, Hendrix College Herbarium, University of Arkansas Herbarium, University of Arkansas at Monticello Herbarium, University of Central Arkansas Herbarium, Austin Peay State University Herbarium, Florida State University—Robert K. Godfrey Herbarium, Harvard University Herbaria, University of Georgia Herbarium, University of North Carolina at Chapel Hill Herbarium, and University of Tennessee Vascular Herbarium accessed through http//:sernecportal.org/index.php. iNaturalist data are available from https://www.inaturalist.org. See supplementary materials.

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Appendix A

Collaborative Georeferencing standard operating procedure for the Vascular Plants of Arkansas project.

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