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Participatory Science in the Field of Ornithology

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Use of the term *citizen science* to describe the centralization of observations by the lay public for scientific purposes was coined in the United States in 1995 at the Cornell Lab of Ornithology. By 2014, the Citizen Science Association formed as the first professional association of practitioners who make citizen science happen by designing, facilitating, evaluating, and examining citizen science and advancing the theory and practice across the discipline. Despite the relatively recent formalization of citizen science as a distinct field of practice (Jordan et al. 2015), and evolving terminology (Table 19.1), the participation of bird-watchers in science activities began long before.

The first wave of environmentalism in the United States was prompted in part by declines in birds, particularly due to overhunting for the millinery (hat-making) industry (Taylor 2016). In the United States during the late 1800s and early 1900s, socially advantaged people with interests in birds formed societies that specifically focused on avian conservation, such as the Audubon Society, the Nuttall Ornithological Society, the American Ornithological Union (AOU), the Wilson Ornithological Society, and the Cooper Ornithological Society, mirroring societies that already existed in Europe such as the British Ornithologists' Union. The power of these societies is evident in the legislation that was passed around the turn of the century at their urging: the Lacey Act and the Migratory Bird Treaty Act, which heavily restricted the killing of birds. This legislation not only restricted bird hunting for hats and food but also put an end to the killing and collection of birds, as well as their nests, feathers, and eggs, by amateur ornithologists—the primary means of ornithological study up until this period. At the same time, binoculars became a more affordable purchase, which allowed for non-extractive bird study. By the late 1800s, it was relatively common for individuals, particularly those who were wealthy, educated, and with leisurely interests in birds, to maintain state- and county-level lists of bird species they had seen (Barrow 2000, Shane 2012).

Over time, these ornithological societies not only advocated for the conservation of birds but also were organizing to study them. For instance, the AOU recruited lighthouse keepers to record the birds they found dead or that struck the lighthouse. The effort failed in part because of a lack of consensus on bird names, with keepers using local colloquial names for birds and AOU scientists unable to figure out what they meant (Merriam 1885, Droege 2007). Around this time, a schoolteacher named W. W. Cooke organized tens of thousands of volunteers to track the timing of bird migrations on standardized note cards. This effort continued into the mid-1900s, and these cards

Table 19.1 Definition of Terms[a]

Term	Definition
Participatory science(s)	A descriptive phrase referring to a range of approaches to scientific activities that involve those without scientific credentials. In this chapter, we refer to *participatory science* as a term that includes both citizen science and community science projects.
Citizen science	Projects in which participants share observations or specimens with a central entity for a shared purpose. These projects are most commonly initiated and administered by large institutions such as the Cornell Lab of Ornithology and the National Audubon Society. This chapter primarily focuses on citizen science. In some contexts, such as in U.S. federal law (i.e., the Crowdsourcing and Citizen Science Act of 2016, H.R. 6414), the term *citizen science* has a broader definition, referring to a range of approaches to scientific activities that involve those without scientific credentials.
Community science	Grassroots, community-driven participatory sciences. In this chapter, we use the term *community science* to refer to projects initiated, administered, and/or coordinated by grassroots efforts, such as the North American Bluebird Society and the Purple Martin Conservation Association. These examples also involve sharing data to a central entity, but participants are often involved in more self-directed activities for the study and conservation of birds.

[a] In recognition of evolving terminology, we define terms in relation to their recent historical use.

were digitized for decades through a project called the North American Bird Phenology Program, organized by the U.S. Geological Survey (Greenwood 2007, Mayer 2010). The Christmas Bird Count began in 1900 as a nationwide survey of birds to replace the earlier tradition of a Christmas bird hunt and was later administered by the Audubon Society. Bird-watchers collated observations among the thousands of participating members and circulated lists in society periodicals (Stewart 1954). The Christmas Bird Count was the first successful and longest running example of citizen science for avian research.

Before the emergence of ornithology as a profession, studies were conducted by people who today we might refer to as amateurs because their primary employment did not involve avian research (Miller-Rushing et al. 2012). By the late 1800s, a distinction began to emerge between paid avian researchers ("professionals") and unpaid bird hobbyists ("amateurs"; Figure 19.1A). As this distinction grew, the research interests of these two groups began to split, with amateurs focused more on local natural history studies, borne of informal education and an interest in local ecology (Vetter 2011).

Amateurs led high-quality studies and made important contributions to ornithology. An amateur birder named J. H. Gurney conducted the first worldwide census of
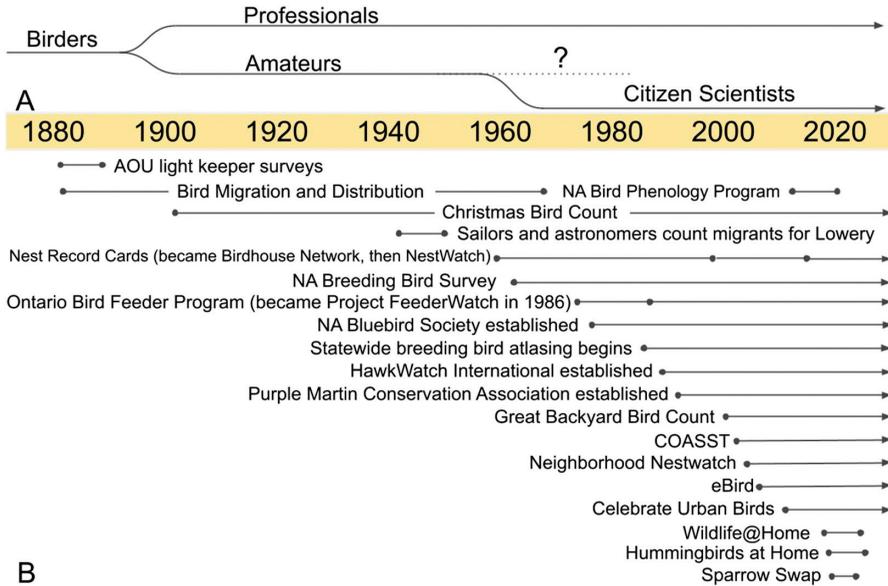
Figure 19.1 Timeline of trends in ornithology and related citizen science activity focused on birds within North America. (A) Bird enthusiasts began separating into professionals and amateurs around 1900. By the 1960s, an offshoot of amateurs became citizen science data collectors, while amateurs leading scientific studies became much less common. (B) A timeline of the emergence of popular avian participatory science activities and organizations in the United States since 1880. Lines ending in a circle indicate that a project ended; lines ending in an arrow indicate a project is still active. Note that the Bird Migration and Distribution program started in 1880 by Wells Cooke stopped in 1970 but then restarted in the 2000s as the North American Bird Phenology Program, whose goal was to digitize the earlier migration records. "Lowery" refers to George Lowery, ornithologist at Louisiana State University. AOU, American Ornithological Union; COASST, Coastal Observation and Seabird Survey Team; NA, North American.

the Atlantic Gannett in 1913, for instance, and a businessman named Arthur C. Bent published 22 volumes of his *Life Histories of North American Birds* series starting in 1919, despite never receiving a salary for his research and lacking formal training in ornithology (Barrow 2000, Greenwood 2007). Other pioneering amateurs of the early 20th century include the Michigan dentist Lawrence Walkinshaw, who wrote an authoritative account of field sparrows based on observations made on an abandoned farm near his home (Mayfield 1991), and Harold Mayfield, a businessman who pioneered new techniques for measuring nest success and was later elected president of the American Ornithologists' Union (Tramer 2007). Indeed, between the 1950s and 1970s, a quarter of all researchers who received the AOU's Brewster medal were amateurs (King and Bock 1978).

Rachel Carson's *Silent Spring* (1962) played a significant role in the emergence of the second wave of environmentalism in the United States, and once again, bird conservation was at the fore of this movement. Carson's book brought to light the

impact of pesticides on ecosystems, and her central premise—that untargeted pesticides might lead to springtime soundscapes without bird or insect songs—had a direct influence on public interest in bird conservation and the subsequent development of the U.S. Breeding Bird Survey (standardized avian surveys along roadsides) and the North American Nest Record Card Program (standardized cards for monitoring nests), which were both launched in the 1960s (Pettingill 1966, Sauer et al. 2017). A decade before Carson's book, however, a retired banker and amateur birder in Florida named Charles Broley, who banded thousands of bald eagles, may have been the first person to suggest a link between the pesticide DDT and egg mortality in eagles and other raptors (Barrow 2000).

In 1974, the National Science Foundation funded a study on the state of ornithology that culminated with a white paper (King and Bock 1978). In the white paper, King and Bock found that half of the members of ornithological societies were amateurs, and the authors encouraged ornithological societies to be prime movers of increasing public participation in ornithology. The societies clearly recognized amateurs as a valuable resource that should be supported, yet the continued professionalization of ornithology coincided with an apparent steady decrease of amateurs in societies. Instead of professional associations taking on the role of promoting and sustaining amateur engagement, the role of nonprofessionals in ornithology was transformed from amateurs producing natural history papers to the engagement of a broader array of bird enthusiasts in data collection through citizen science projects organized by institutions such as federal agencies, the National Audubon Society, and the Cornell Lab of Ornithology.

Web 2.0 technologies emerged in the early 2000s and allowed users of online spaces to add content, making it easier for scientists to create citizen science projects that can accept observation via the internet. At the same time, the rise of social media fostered a culture of online sharing. In this atmosphere, the number of citizen science projects continued to grow, including fully online projects in which volunteers assisted in transcribing text and annotating photographs and videos (Figure 19.1B).

The history of participatory science creates a legacy of data in ornithology. For example, in large part because of well-kept records of bird clubs, nest monitoring projects, and banders, half of what is understood about migratory birds and climate change is based on studies that leveraged these types of crowdsourced data (Cooper 2014). These studies involved participants contributing bird checklists, banding/resighting birds, and monitoring nesting birds. Although these three activities form the basis of most avian citizen science, Web 2.0 technologies have enabled other ways for bird enthusiasts to contribute to ornithological research. With the rise of the internet, the smartphone, and big data visualization, an even more expansive vision for ornithological citizen science has emerged.

Successes of Ornithological Citizen Science

The greatest value of avian citizen science is in the broadscale data sets it generates, which would be otherwise logistically or financially unfeasible for scientists to generate on their own. Whereas some citizen science projects are structured to

test specific hypotheses, many collect baseline information on many aspects of avian species, such as population size, range, migration phenology, reproductive success, and mortality rates and causes.

Volunteer-generated data have high variability (e.g., measurement error) and bias (e.g., spatiotemporal clustering). Projects recognize and address data quality issues by, for example, providing volunteer training, data standardization, validation and filtering procedures, and other actions to reduce sources of error and bias before, during, and after data are collected (Wiggins et al. 2011, Bonter and Cooper 2012). For instance, the Cornell Lab of Ornithology's Bird Academy provides trainings in citizen science practices and bird identification that can improve citizen scientists' data quality, and the Lab also has automated processes that use algorithms to flag potentially inaccurate data records submitted to their projects (Sullivan et al. 2014). All data have both strengths and limitations that are important to recognize (including data collected by scientists), and the types of limitations associated with citizen science data can be specific to the volunteer activity and type of data collected. We review some areas of success associated with different participant activities.

Specimen Collection

During the European Renaissance, it was fashionable for wealthy European men to collect birds, as well as other animals, and classify, catalog, and preserve them in "cabinets of curiosities." Some of these efforts were participatory. For instance, in the 1500s, Pierre Belon encouraged people to send him bird specimens from throughout the world, from which he produced a book of woodcut bird illustrations (Chansigaud 2010).

The colonial roots of ornithology are apparent as the practice of collecting specimens grew and evolved during the 17th and 18th centuries, with governments in Western Europe sponsoring voyages around the world to lay claim to new territories and extract resources. Museum and university collections grew with thousands of specimens that explorers collected (Chansigaud 2010). For example, in the early 1800s, on the Lewis and Clark expedition, explorers made significant efforts to describe the birds they saw and collect bird specimens (Davis and Stevenson 1934). In the 1850s, Spencer Fullerton Baird, as the first curator of the Smithsonian Institution, recruited doctors in the U.S. Army to collect birds on their journeys (Shane 2012).

Collections have been used for significant findings, such as the role of DDT in eggshell thinning (Hickey and Anderson 1968). Today, specimen collection is a fairly uncommon citizen science activity, partly restricted by the Migratory Bird Treaty Act and other laws protecting wildlife. Collections of skins, nests, and shells provide useful biological vouchers for DNA, contaminant data, and stable isotope measurements. For example, Full Cycle Phenology is a project that relies on the volunteer collection of feathers to better understand kestrel migration (Joray 2020). Sparrow Swap was a project in which volunteers mailed the eggs of House Sparrows (a non-native species not protected by the law in the United States) to the North Carolina Museum of Natural Sciences for analysis of heavy metals and egg color patterns (Hartley 2019). Feather

Map of Australia involves volunteer collection of feathers and lab analyses of stable isotopes (Brandis et al. 2021).

Bird-Watching Checklists

One of the most prominent and straightforward types of volunteer data contribution is the checklist of wild living birds encountered. The most popular checklist project is eBird, by the Cornell Lab of Ornithology. Volunteers contribute to eBird using a mobile app to record the number of birds of different species they see in a given area and for a given amount of time. As of 2022, more than 800,000 citizen scientists had contributed more than 1 billion bird observations and 70 million checklists across more than 200 countries. Few, if any, citizen science projects, from any discipline, approach the magnitude of data generated by eBird, and the scope of this project is a noteworthy development in the history of science. In 2021, eBird volunteers submitted more than 1 million records of Red-Tailed Hawks alone—a species whose total global population is estimated to be approximately 3 million (Partners in Flight 2020). Acknowledging the fact that some of these records are of the same individual bird, it is still remarkable that data are being collected from a substantial fraction of all members of an entire species.

Data from eBird have been used in more than 100 peer-reviewed publications and many management plans. For instance, La Sorte et al. (2017) used eBird data to examine large-scale bird migration patterns, specifically whether nocturnal migratory birds are attracted to artificial lights at night in urban areas. In addition to eBird, other projects use various forms of checklists, such as the Cornell Lab's Project FeederWatch, which tasks volunteers with counting birds that visit feeders; Audubon's Climate Watch, in which volunteers count 12 species at a specific location twice per year; and the U.S. Geological Survey's North American Breeding Bird Survey, in which volunteers count birds along randomly established roadside routes. An offshoot of Project FeederWatch, the House Finch Disease Survey, tasked volunteers with maintaining checklists of House Finches with visible conjunctivitis to track the spread of avian disease (Hochachka and Dhondt 2000). Checklist data are most often used to better understand avian population dynamics, the distribution of invasive species, endangered species management, and how birds respond to climate change and urbanization.

Checklists provide three main types of data about living birds (Bird et al. 2014): presence-only observations (Is a species present in an area?), presence *and* absence observations (Is a species present in an area and not in another?), and counts (the number of individuals of each species observed). In addition, checklist data can be structured, unstructured, or semistructured—a distinction that applies to any citizen science data. Unstructured data are opportunistic and can be collected at any time and place, such as bird observations submitted to the project iNaturalist (Callaghan et al. 2019). Unstructured projects lower barriers to participation because they require little or no training and can thereby involve more volunteers, resulting in a higher likelihood of observing rare events or species. However, the nature of

unstructured data results in spatial, taxonomic, and other biases, such as concentrations of observations in urban areas, overrepresentation of large or interesting species, and underrepresentation of common species (Kamp et al. 2016, Callaghan et al. 2019). Structured projects, on the other hand, such as the North American Breeding Bird Survey and Breeding Bird Atlas programs, rely on formal protocols for data collection, which can result in a more robust understanding of distributions but at the cost of engaging fewer volunteers due to the higher degree of volunteer training required (Bowler et al. 2022). Semistructured projects, such as eBird, utilize flexible protocols, such as allowing volunteers to choose whether they will submit a robust checklist of every individual seen or a more casual checklist of the individuals or species of interest to the contributor (Kelling et al. 2019). Measuring survey efforts, standardizing data collection protocols, and accounting for observers' biases can improve data quality and contribute to more robust estimates of avian diversity and abundance from checklists. In addition, because volunteers often participate in multiple projects, citizen science projects can be scaffolded such that volunteers first gain foundational skills in simpler unstructured projects before moving on to contributing high-quality data to more complicated structured projects (Allf et al. 2022).

Nest Monitoring

Whereas checklisting is heavily derived from British colonial culture, interest in managing and monitoring nesting has broader cultural roots. For instance, the Chickasaw and Choctaw, and other Indigenous groups in the eastern areas of what is now the United States, influenced the colonial breeding habits of Purple Martins—specifically their breeding in clusters of hollow gourds provided by people—long before the first European settlers (Doughty and Fergus 2002).

Although bird enthusiasts can potentially find and share data about any nesting species, the most commonly monitored are those using nesting sites provided by people. Most instances of grassroots community science focused on birds have been (and continue to be) related to the provisioning of nesting sites. Grassroots community science has supported bird conservation, particularly of target species commensal with humans. There are three species that now mostly depend exclusively on human structures for breeding in the United States—the Purple Martin, Chimney Swift, and Barn Swallow—and community science has played a significant role in the management of at least two of them (Chimney Swifts and Purple Martins). For example, in 1987, the Purple Martin Conservation Association (PMCA) was formed in order to better organize conservation efforts related to martins. The PMCA later created Project Martin Watch, the Purple Martin Survey, and the Scout-Arrival Study, each of which engages volunteers (particularly landowners with artificial Purple Martin roosts) with collecting data about martin nesting success, migration phenology, and other information. The PMCA also sells roosts and shares educational information about Purple Martins with volunteers.

Another group of species that relies heavily, but not exclusively, on human structures is bluebirds. There has been significant community science and citizen science organized around each of the three species of bluebirds in the United States. Volunteer-generated bluebird data support studies of population trends, population dynamics, phenology, seasonal and geographic patterns, habitat comparisons, and more. For instance, data from bluebird monitors in The Birdhouse Network (predecessor to the Cornell Lab's NestWatch project) were used to understand differences in clutch size in the Eastern Bluebird across latitudes (Cooper et al. 2005). Nest monitoring data have also been influential in understanding phenological responses to climate change (Crick and Sparks 1999). In fact, the work of Crick and Sparks with the British Trust for Ornithology's Nest Record Scheme was cited to urge policymakers to ratify the Kyoto Protocol, an international treaty that extended the United Nations Framework Convention on Climate Change. NestWatch observers have documented patterns of egg incubation (Nord and Cooper 2020), twinning in wild bird eggs (Bailey and Clark 2014), and the influence of sensory pollutants (noise and light) on breeding phenology and reproductive fitness across the United States (Senzaki et al. 2020). Cameras mounted on nests have expanded public engagement in nest monitoring—2 million people every month watch the Cornell Lab's nest cameras alone (Saulnier 2021)—and scientific insights, such as the development of new proximate mechanisms for determining clutch size (Cooper et al. 2009). CitSciGrid was a platform that hosted several citizen science projects, including Wildlife@Home, which engaged participants in the processing of images and videos of nesting birds (Desell et al. 2015). Like other forms of data collection, nest monitoring data contain bias, such as increased frequency of observation on weekends, which can be resolved with analytical techniques such as backdating (Cooper 2014).

Banding

Bird banding in the United States dates back to at least the early 1800s, with John James Audubon's early attempts to band Eastern Phoebes with silver wire (Jackson et al. 2008). Currently, the U.S. Fish and Wildlife Service administers a program of bird banding permits, with a system for sub-permittees. In some citizen science projects, participants can work as sub-permittees, such as through the Monitoring Avian Productivity and Survivorship (MAPS) project (DeSante 1992). MAPS, an initiative of the Institute for Bird Populations, started in 1989 and produces avian productivity indices based on ratios of young and adult birds captured in mist nets, and it estimates adult apparent survival and population growth rates based on band-recapture statistical methods (DeSante et al. 1995). In other projects, participants serve as location hosts for bird banding on their property, such as with the Smithsonian Institute's Neighborhood NestWatch (Evans et al. 2005). In addition, well-established banding stations, such as Braddock Bay Bird Observatory in New York, Point Reyes Bird Observatory in California, and Powdermill Nature Preserve in Pennsylvania, have programs for volunteers. Banding data support studies of migration rates, migration phenology, adult survival rates, and related population studies.

Dead Bird Monitoring

Citizen science efforts play a critical role in monitoring avian mortality. Perhaps the best known of these projects is the Coastal Observation and Seabird Survey Team (COASST), which relies on volunteers to monitor the occurrence of beached birds—that is, birds found dead on beaches. COASST was started in 1999 to document baseline levels of beached birds and subsequent departures from baseline, as well as to investigate the causes of mortality events and to create predictive models of mortality events. COASST participants follow standardized protocols that volunteers helped develop (Parrish et al. 2017). COASST engages approximately 800 monthly collectors across 450 sites between northern California and Utqiagvik, Alaska, and west through the Aleutians (Parrish et al. 2022). COASST baseline data have served as a sort of scientific anchor, allowing the research community to understand the severity and geographic and taxonomic breadth of multiple marine bird mass mortality events collectively resulting in the death of several million birds. COASST makes contributions to ornithology; for example, it has submitted 60 significant bird records to the Washington Bird Records Committee of the Washington Ornithological Society, including four species with no previous record of occurrence in Washington (Least Auklet, Wedge-Tailed Shearwater, Red-Footed Booby, and Purple Gallinule), and it has reclassified the Horned Puffin as a regularly occurring species rather than a rare species (Julia Parrish, University of Washington, personal communication). COASST contributes to management, as evident from the hundreds of data requests it receives from federal agencies, academic groups, nongovernmental organizations, and state wildlife agencies. For instance, the National Oceanic and Atmospheric Association uses COASST baseline data in its annual ecosystem assessments in California and Alaska (Julia Parrish, personal communication).

Another type of dead bird monitoring focuses on collecting and analyzing observations of bird collisions with built structures. The earliest documented record of a bird–window collision in North America was by Nuttall (1832), who observed a Sharp-Shinned Hawk (*Accipiter striatus*) collide with windows while pursuing prey. Today, a variety of citizen science projects collect observations of bird–window collisions, such as Minnesota Project BirdSafe and the Fatal Light Awareness Program (Cusa et al. 2015, Nichols et al. 2018). Science museums also play an important role in keeping bird–window collision records because many bird carcasses collected by surveyors are brought to museums to be added to ornithological collections. As more people have become aware of the collision issue, the number of collision monitoring projects and the number of published articles on bird–window collisions have increased, and these projects have been at the forefront of Lights Out campaigns to reduce light pollution that causes nocturnal migrants to collide with buildings, as well as campaigns to retrofit high-collision-risk windows with films and stickers that make building windows more visible to birds (Basilio et al. 2020).

Bird–window collision projects can be structured, using standardized surveys of targeted buildings over a period of time, or unstructured, making use of opportunistic observations, such as the Bird–Window Collisions project on iNaturalist (Winton et al. 2018). One benefit of bird–window collision projects is that they are often easy to participate in; collecting these observations does not require the bird identification

skills needed to participate in eBird, for instance. Whereas most of these projects collect contemporary data, some studies have used memory-based surveys that ask volunteers if they have seen birds strike windows in the past (Kummer et al. 2016).

Experiments

Most ornithological citizen science projects focus on observational data such as bird counts, but there are some projects that engage citizen scientists in conducting ecological experiments. One study recruited volunteers who were enrolled in Project FeederWatch to participate in a hawk playback experiment in people's yards (Zuckerberg et al. 2022). A randomized control-treatment design was used to ask participants to broadcast either hawk or goldfinch calls to backyard birds. Participants recorded birds' anti-predator behavior before, during, and after playback, and researchers used these data to explore how urbanization influences birds' behavior. In a different study, in 1993 the Cornell Lab recruited volunteers to put white millet, red milo, or black-oil sunflower seeds on separate pieces of cardboard and then test which bird species fed on which seeds (Trumbull et al. 2000). In general, experiment-based citizen science projects are uncommon due to the complexity of the tasks that volunteers are required to carry out.

Impacts for Participant Learning

Avian citizen science has benefits beyond its ecological value. An emerging research practice focuses on evaluating the "learning outcomes" of participation in these projects—that is, how experiences in avian citizen science lead to an increased understanding of science, ecology, and/or conservation. For instance, one study found that participants in The Birdhouse Network increased their knowledge of bird biology, according to comparisons of surveys taken before and after volunteers participated in the project (Brossard et al. 2005). In addition, some participants in this project set up their own experiments related to The Birdhouse Network project or engaged in more "pro-bird" behaviors such as erecting nest boxes, indicating the potential for avian citizen science to inspire volunteers to more deeply pursue scientific inquiry and to change their conservation behaviors, respectively (Brossard et al. 2005, Bonney et al. 2009). Other studies have found that volunteers with the Smithsonian Institute's Neighborhood Nestwatch program increased their ecological literacy and their sense of the value of backyard habitats for birds (Evans et al. 2005), that kindergarten through grade 12 participants in the curriculum-based Cornell Lab project BirdSleuth increased their knowledge of bird biology and identification (Thompson 2007), and that nest box monitors are more likely to manage for invasive bird species than people who do not do nest monitoring (Phillips et al. 2021). In general, citizen science is often shown to increase volunteers' scientific or ecological knowledge; changes in higher level cognitive processes such as pro-environmental attitudes, pro-environmental behaviors, and conceptualizations of science and scientific

epistemologies are rarer, due in part to the fact that many citizen science volunteers enter into projects already highly interested in, and engaged with, science and nature (Brossard et al. 2005, Pandya and Dibner 2018). Designing project protocols to achieve learning goals requires intentionality; projects designed solely to accomplish scientific goals without considering volunteers' needs are generally poorly equipped to also have significant value for learning. In addition, documenting changes in volunteers' knowledge or beliefs inherently requires engaging volunteers who enter into projects with "room to grow" in terms of their baseline knowledge or beliefs about birds and conservation.

Room for Improvement

Neither professional ornithology nor citizen science has produced research representative of the distribution of birds. For example, the ornithological literature is dominated by studies from the Global North (Europe, the United States, and Canada) despite the fact that more than one-third of all bird species live in the Neotropics (E. Blake 1977, Hedblom and Murgui 2017). Similarly, although approximately 84% of the Earth's terrestrial surface contains bird occurrence information, these data are concentrated in North America, Europe, India, Australia, and New Zealand, and more than half of eBird checklists come from the United States alone (La Sorte and Somveille 2020). Gaps in data on bird occurrences are most prevalent in central South America, northern and central Africa, and northern Asia (La Sorte and Somveille 2020). These trends reflect the birding legacy of British colonization. In addition, ornithology is part of the hegemonic structure of science, with dominant narratives in the English language and research priorities dictated by those in the Global North. Citizen science counters the hierarchical systems of Eurocentric science by valuing the observations of those without scientific credentials. Nevertheless, citizen science reinforces colonial Western reductionist approaches to science and mimics the extractive practices of imperial scientists taking specimens to European museums. In addition, citizen science typically does not situate other forms of knowledge about birds from different cultures and perspectives into ornithology.

Although approximately one-third of adults in the United States go bird-watching, at least on occasion (Cordell and Herbert 2002), participant demographics are not representative of the general population. In the United States, this demographic skew is particularly prominent in terms of race and ethnicity. For example, in a survey with more than 3,000 respondents, 96% of Christmas Bird Count participants identified as White and non-Hispanic (Allf et al. 2022). Citizen science across disciplines shows similar trends (C. Blake et al. 2020, Pateman et al. 2021, Mahmoudi et al. 2022). Citizen science initiatives such as the Cornell Lab's Celebrate Urban Birds project are attempting to foster greater diversity in avian citizen science by collaborating with existing local organizations to engage diverse communities in avian study (Purcell et al. 2012). Celebrate Urban Birds makes program materials available in both English and Spanish and offers mini-grants to enable partner organizations to use project resources to create their own bird-related events. Although not citizen science per se,

Table 19.2 Types of Bird-Related Recreation Activities[a]

Bird-Related Activity	% Male (*n*)	% Female (*n*)
Supportive (least competitive)	46 (508,113)	54 (587,233)
Participatory (moderately competitive)	55 (45,312)	45 (37,800)
Competitive (highly competitive)	97 (6,815)	2 (118)
Authoritative (most competitive)	90 (230)	10 (26)

[a] Women were much less likely to participate in the more competitive activity types.

Source: Extracted from Cooper and Smith (2010).

Black Birders Week, a week-long event series meant to increase the visibility of Black birders in response to the harassment of a Black birder in New York City, is another initiative meant to create space for more diverse bird-watching communities.

Gender patterns are another important consideration in the design of inclusive ornithological citizen science. For instance, competitiveness in birding culture affects gender disparities in engagement and the design of citizen science projects (Table 19.2) (Cooper and Smith 2010). Specifically, women are less likely to be competitive birders (e.g., participate in the World Series of Birding). More generally, women are also less likely to be in positions of authority in avian citizen science (e.g., eBird reviewers; Cooper and Smith 2010).

Physical accessibility barriers also exist that can limit participation in ornithological citizen science. Indeed, 35% of wildlife viewers report that they experience accessibility-related challenges, including those related to mobility, vision, hearing, mental or chronic illness, intellectual or developmental disabilities, or neurodiversity—which means a sizable portion of citizen science participants likely experience these challenges as well (Sinkular et al. 2022). Disabilities also increase with age, and many avian citizen science volunteers are middle-aged or older (Allf et al. 2022). Birdability, a nonprofit with the mission of sharing the joys of birding with people who have disabilities, publishes an international map of birding locations that are accessible to people needing special accommodations, such as places to sit, paved terrain, tactile or Braille signs, and even the dimensions of bathroom sinks at birding locations. As was made clear during the COVID-19 pandemic, group size and whether or not an activity is indoors are important considerations for people with compromised immune systems and are important considerations in inclusive design. This is not to say that all birding activities must take place outdoors in small groups; rather, projects should be clear about the accommodations that are afforded to participants and what volunteers with different needs can expect from an activity. Making ornithological citizen science more accessible can also involve providing special equipment such as wheelchair-mounted scopes, trail chairs, table "digiscoping" adaptors for scopes, binocular mounts, winged eyecups for binoculars, outdoor microphones, hearing-assistance devices, car window mounts, and more.

Financial barriers to participating in avian monitoring also exist. Some ornithology projects require significant costs (e.g., Earthwatch expeditions) or low costs (e.g., Project FeederWatch), and any costs can create a barrier to entry and participation.

Wealth-based barriers can occur without direct fees, such as the cost of purchasing binoculars or spotting scopes; costs involved with setting up feeders, nest boxes, or providing supplemental food; and even costs associated with time commitments or required flexibility at particular times of day. Each of these factors can skew participation. Even among people who can afford the financial commitment of a citizen science project, those with lower incomes may simply weigh the cost more heavily when considering to what degree to pursue a project than people with higher incomes.

For two main reasons, avian citizen science would be improved by broadening the diversity of volunteers who participate in projects. First, participating in citizen science confers benefits on participants, such as gaining new skills, new social connections (e.g., with other volunteers or with scientists), or a stronger connection to nature in their community. If most people who do citizen science are White, educated, able-bodied, and/or wealthy, then the practice is concentrating these benefits among people who are already well-resourced in our society. Broadening the diversity of participants in citizen science can also simply result in higher quality data (C. Blake et al. 2020, Mahmoudi et al. 2022). For instance, projects that oversample wealthy neighborhoods compared to poorer minority communities are generating biased data. Minority communities are often disproportionately burdened with air and water pollution and lower tree canopy cover that may affect local bird populations. Thus, an urban ornithological project might give an unrealistically optimistic portrayal of a city's bird populations if it does not collect data from regions where bird populations are suffering due to environmental contamination and habitat degradation. Broadening volunteer diversity starts with reaching out to and connecting with new communities, but it cannot end there; these relationships must be nurtured through sustained engagement with the goals and interests of volunteers and the public. This might involve gamification of project protocols, giving volunteers more autonomy to pursue their own research questions, and/or providing more opportunities for social interactions among volunteers.

Conclusion

Throughout the history of ornithology, amateurs have made important contributions to avian science. Although the professionalization of ornithology and the rise of citizen science have coincided with a reduction in amateurs leading full-blown research studies, amateur participation in the study of birds remains high, and the amount of data generated by these volunteers is unrivaled by the efforts of amateurs working in any other scientific discipline. Indeed, more than half of all records of any species in the Global Biodiversity Information Facility are of birds, despite the minuscule fraction of global species that are birds. These data have resulted in hundreds of publications and new understandings of avian migration, feeding, breeding, and mortality. Avian citizen science has also enabled millions of people to connect with the natural world and contribute to science.

Citizen science data, like all data, have inherent biases, and avian citizen science can be highly spatially biased, in particular. To remedy this patchiness, two

approaches have been suggested. In one approach, incentive systems, including gamified approaches, encourage current participants to make the most meaningful contributions by sampling in rural and remote undersampled areas (Xue et al. 2016, Alexandrino et al. 2019). In another approach, participatory science projects are encouraged to pursue inclusive and equitable methods for engaging *new* participants living in, near, or with attachment to undersampled areas (Cooper et al. 2021). Apps such as Merlin, which uses artificial intelligence to assist novices with bird identification, have the potential to improve the skill level of volunteers who enter into projects with less birding experience. The great successes experienced by ornithological citizen science thus far could be magnified further if projects broaden participation.

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