**CITIZEN SCIENCE:**

**THE 21ST CENTURY'S BEST 'NEW' TOOL FOR CONSERVATION?**

by

MINDY CAROL EDELSON

(Under the Direction of Ronald Carroll)

ABSTRACT

Although the first Citizen Science project dates back as early as 1900, it was not until recently that scientists in a variety of disciplines began employing citizen science programming. These projects seek to gather broad-scale data, often from a large geographic range, by recruiting volunteers to act as data-gathering devices. This results in scientists getting much more data in a shorter period of time, and citizens getting educational and recreational experiences. Citizen science is a multi-disciplinary field, drawing from the sciences as well as the social sciences, and as a result the field is dynamic and holds great potential. Many fields of science can benefit from incorporating citizen science techniques, but conservation ecology seems to be the most relevant and welcoming field. This thesis assesses the 'gaps' in citizen science – such as taxonomic and subject-matter disparities – and makes recommendations to citizen science project coordinators for the future of this burgeoning field.

INDEX WORDS: Citizen Science, Environmental Education, Science Education, Conservation Education.

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DEDICATION

To science!

Somebody said that it couldn’t be done
But he with a chuckle replied
That “maybe it couldn’t,” but he would be one
Who wouldn’t say so till he’d tried.
So he buckled right in with the trace of a grin
On his face. If he worried he hid it.
He started to sing as he tackled the thing
That couldn’t be done, and he did it!

Somebody scoffed: “Oh, you’ll never do that;
At least no one ever has done it;”
But he took off his coat and he took off his hat
And the first thing we knew he’d begun it.
With a lift of his chin and a bit of a grin,
Without any doubting or quiddit,
He started to sing as he tackled the thing
That couldn’t be done, and he did it.

There are thousands to tell you it cannot be done,
There are thousands to prophesy failure,
There are thousands to point out to you one by one,
The dangers that wait to assail you.
But just buckle in with a bit of a grin,
Just take off your coat and go to it;
Just start in to sing as you tackle the thing
That “cannot be done,” and you’ll do it.

***Edgar Albert Guest, 1919***

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TABLE OF CONTENTS

LIST OF FIGURES

# CHAPTER 1 - INTRODUCTION

## Literature Review

### *Conservation Ecology*

The field of conservation ecology, although relatively new as a profession, has manifested in other forms for quite some time. Conservation has its origins in many cultures around the world, but in the United States the conservation movement began in the 19th century. The field of ecology began its canonization in the 19th century as well. It was not until the early 1980s that the fields of conservation and ecology began to overlap into a new discipline.[1] Perhaps an ecologist today would define conservation as a movement to protect the Earth's natural resources and habitats for the future. This definition is dynamic, as the field of conservation ecology is interdisciplinary. It "applies the principles of ecology, biogeography, population genetics, economics, sociology, anthropology, [and] philosophy"[2] towards the goal of maintaining biodiversity.

The science of conservation ecology today is perhaps the most important measure of conservation outcomes. We now possess the science and technology to predict when a species will go extinct, yet we can also measure how successful a conservation program has been in the recovery of a species.[3] While the scientific process is a direct way to contribute to conservation, there are other aspects of conservation that help the process in

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[1] Soule, M. E., & Wilcox, B. A. (1980). *Conservation biology. An evolutionary-ecological perspective*. Sinauer Associates, Inc..
[2] Groom, M. J., Meffe, G. K., & Carroll, C. R. (2006). *Principles of conservation biology* (p. 6). Sunderland: Sinauer Associates.
[3] Brook, B. W., O'Grady, J. J., Chapman, A. P., Burgman, M. A., Akçakaya, H. R., & Frankham, R. (2000). Predictive accuracy of population viability analysis in conservation biology. *Nature*, *404*(6776), 385-387.

more indirect ways.  Since conservation ecology is an interdisciplinary field, it should come as no surprise that its approaches to conservation tactics are multifaceted as well. Advocacy is a popular method of conservation used by nonprofit organizations and research institutions alike.  Hands-on projects that involve the community are another popular way to conserve biodiversity.  For example, there are many projects centered on invasive species eradication (eg. privet pulls), which indirectly help conservation initiatives by encouraging native biodiversity.[4]  Advocacy and hands-on projects are both effective tools for conservation, but perhaps the most effective tool that indirectly aids in conservation is environmental education.

Conservation success is measured in a number of different ways.  A species that has recovered from the brink of extinction – such as in the case of the American Bald Eagle – is revered widely as a conservation success.[5]  But is species recovery the only indicator of true conservation?  While it is a big part of what conservationists aim to do, it is not their only goal.  One bottom-up approach to conservation is to tackle environmental attitudes and environmental literacy.  It is believed by many researchers in science education that positive environmental attitudes (biophilia) and increased environmental literacy may yield increased environmental stewardship, although this framework is very difficult to study.[6] [7]  In other words, when people see the value of and are knowledgeable about the natural world, they will want to conserve it.  The body of

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[4] Randall, J. M., & Marinelli, J. (Eds.). (1996). *Invasive plants: weeds of the global garden* (Vol. 149). bbg. org/handbooks.

[5] "Bald Eagles:  Life History and Conservation Success".  Retrieved May 21, 2013, from http://www.fws.gov/midwest/eagle/recovery/

[6] Kruse, C. K., & Card, J. A. (2004). Effects of a conservation education camp program on campers' self-reported knowledge, attitude, and behavior. *The Journal of Environmental Education*, *35*(4), 33-45.

[7] Siemer, W. F., & Knuth, B. A. (2001). Effects of fishing education programs on antecedents of responsible environmental behavior. *The Journal of Environmental Education*, *32*(4), 23-29.

literature surrounding this idea is diverse, and the methodology designed to measure environmental attitudes and literacy has come in many forms. Nevertheless, most organizations dedicated to environmental conservation include some kind of educational programming in the hopes that it will indirectly help with their conservation goals.

In the process of discussing the history and evolution of conservation ecology, one must address the topics or 'pressing issues' that face conservation ecologists. This is, of course, dynamic – and the pressing issues identified by a conservation ecologist may differ from those identified by an ecologist with no conservation focus. However, recent literature has given us some idea of what the majority of conservationists today think are the most important topics to research. They are, in no particular order, 1) species invasions, 2) resource management, 3) infectious diseases, 4) air quality, 5) water quality, 6) loss of biodiversity, 7) loss of ecosystems and ecosystem services, and 8) global climate change.[8] [9] [10] These topics form the basis of nearly all papers published by conservation ecologists.

Conservation ecology is inherently an ethical issue.[11] The fact that there are scientists, attorneys, legislators, and educators all working towards a common goal of environmental conservation means that many people care about the resources that they are conserving in the first place. This asserts the standpoint that imperiled organisms and habitats are worth saving, and deserving of time, effort, money, and countless other resources. Many people do not agree with this standpoint and argue that our resources

[8] Soulé, M. E., & Orians, G. (Eds.). (2001). *Conservation biology: research priorities for the next decade*. Island Press.
[9] Wallington, T. J., Hobbs, R. J., & Moore, S. A. (2005). Implications of current ecological thinking for biodiversity conservation: a review of the salient issues.*Ecology and Society*, *10*(1), 16.
[10] Straughan, B. (2008). The broader movement: Nonprofit environmental and conservation organizations, 1989-2005.
[11] Tisdell, C. A. (1989). Environmental conservation: Economics, ecology, and ethics. *Environmental conservation*, *16*(02), 107-112.

would be better spent on humanitarian issues, such as helping the needy and curing human diseases.  Indeed, those are very pressing issues facing all parts of the world, but does that mean that human issues and environmental issues are mutually exclusive of one another?  Must citizens choose people OR the environment in their funding decisions? Many conservation scientists argue that these issues are not separate but, in fact, linked to one another.[12]

While conservation ecology does support a very distinct ethic – the ethic of valuing all living things and not just humans – it does so with as much scientific basis as possible.  That is, conservation ecologists do not support valuing all living things on the planet simply because they are kind – they do so because of scientific support for the integrative nature of food webs, where each living thing has a unique and important function.[13]  One example of this is in the provision of ecosystem services.  These are functions in our environment that are the result of specific interactions that take place between living and non-living things.[14]  The pollination of flowering plants by birds and insects is an ecosystem service that we often take for granted.  If just one of these variables – the flowering plants, the birds, or the insects – were to be depleted by any number of causes (land degradation, global climate change, disease, etc.), the ecosystem service would cease to exist, or at the very least would be hindered.   In turn, this would

[12] Blench, R. (1998). *Biodiversity conservation and its opponents*. Overseas Development Institute.
[13] Pullin, A. S., Knight, T. M., Stone, D. A., & Charman, K. (2004). Do conservation managers use scientific evidence to support their decision-making?. *Biological conservation*, *119*(2), 245-252.
[14] De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological economics*, *41*(3), 393-408.

impact crop production and food stores for the entire human population.[15] In other words, many years of research has provided scientific evidence that protecting species and habitats yields a better functioning planet – for both humans and non-humans alike.

Nevertheless, many people argue that protecting our environment is a value judgment and therefore we should not be teaching it in our public schools because it is up to parents to decide what values to teach their children. The counterargument to this is that there are, in fact, many things public education conveys to our children that are based on a chosen set of values.[16] Do we not teach children nationwide to be kind to one another, not to bully, and give our teachers, fellow students, and ourselves respect? Do we not teach children to give back to the needy by volunteering our time, donating money, and providing other services? Teaching the ethic of conserving the environment is just the same – but instead of giving back to needy people, we are giving back to a needy environment.

Another ethical topic that is often broached among conservation scientists is the issue of conservation bias towards charismatic megafauna. Charismatic megafauna are large animal species that tend to have popular appeal due to physical or behavioral attributes.[17] For example, the giant panda has been one of the world's most beloved animals for quite some time. Many people attribute the panda's popularity to its furry and 'cuddly' appearance, while others attribute it to the panda's bumbling, playful

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[15] Kremen, C., Williams, N. M., Aizen, M. A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., ... & Ricketts, T. H. (2007). Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology Letters*, *10*(4), 299-314.

[16] Scott, W., & Oulton, C. (1998). Environmental values education: An exploration of its role in the school curriculum. *Journal of Moral Education*, *27*(2), 209-224.

[17] Lunney D 2012, 'Charismatic megafauna' in *The Encyclopedia of Sustainability: Vol. 5. Ecosystem Management and Sustainability*, Craig RK, Pardy B, Nagle JC, Schmitz O & Smith W (eds), Berkshire Publishing, Great Barrington, MA, USA

nature.[18] Despite these perceptions about wildlife often being inaccurate, they often aid in generating interest in funding wildlife conservation. The problem manifests in the fact that there is no correlation between how charismatic a species is and how 'needy' it is of conservation. While there are definitely cases of critically endangered megafauna (eg. the panthers in Florida[19]), there are also cases of critically endangered plants, insects, and sponges they often get overlooked because the average person does not find them as superficially appealing. Some conservationists argue that although it may be unfair and illogical to exhibit a funding preference for charismatic megafauna, it is at least a step in the right direction. If animals like pandas can be used as a flagship species, at least the general public will take a vested interest in some sort of conservation – which is better than funding nothing at all.[20] In other words, these charismatic megafauna are a gateway into the world of environmental conservation; the cute, cuddly animal may initially 'hook' a potential donor, who may then go on to donate to other worthier causes. Another case for this is that species conservation usually entails habitat or ecosystem conservation. In order to conserve wild giant pandas, whose numbers are dwindling in large part due to habitat fragmentation, one must preserve tracts of land in bamboo forests and create corridors connecting isolated forests.[21] A side effect of conserving this habitat is that it benefits not only pandas, but other indigenous organisms as well (including plants and insects). If using the giant panda as a flagship species for habitat

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[18] Leader-Williams, N. I. G. E. L., & Dublin, H. T. (2000). Charismatic megafauna as 'flagship species'. *Priorities for the conservation of mammalian diversity: Has the panda had its day*, *3*, 53-81.

[19] Florida Panther Conservation. Retrieved May 22, 2013, from http://pantherconservation.com

[20] Dietz, J. M., Dietz, L. A., & Nagagata, E. Y. (1994). The effective use of flagship species for conservation of biodiversity: the example of lion tamarins in Brazil. In *Creative conservation* (pp. 32-49). Springer Netherlands.

[21] Xu, W., Ouyang, Z., Viña, A., Zheng, H., Liu, J., & Xiao, Y. (2006). Designing a conservation plan for protecting the habitat for giant pandas in the Qionglai mountain range, China. *Diversity and Distributions*, *12*(5), 610-619.

conservation means that the entire ecosystem will benefit, then perhaps bias towards charismatic megafauna is permissible. As E.O. Wilson once said, “Our most easily appreciated species can call attention to the plight of our entire ecosystem.”[22]

While the charismatic megafauna debate is still contested, the issue infiltrates into environmental education as a tool for conservation. Should educational efforts reflect species that are in most need of conservation, or should we try to ‘hook’ students on charismatic animals that will have more of an impact?[23] It is not difficult to see how some would interpret this problem as a marketing issue. This is essentially trying to sell the idea of conservation in educational programs.

*Environmental Education*

Environmental education (EE) has a fascinating history. Much like conservation ecology, its official establishment as a professional field has been in recent years. As discussed previously, the interest in learning and teaching about the environment dates back centuries. The first big proponents of environmental education were Jean-Jaques Rousseau (an 18th century educational philosopher) and Louis Agassiz (an 19th century scientist), who both endorsed learning from nature. In the early 20th century, the field of ecology as a scientific discipline really began to take shape, and by the 1930s the Dust Bowl had given rise to a federally supported conservation education movement. By the mid 1940s, the University of Wisconsin – Stevens Point was offering a degree in

[22] Saving “charismatic” animals. (1985, April 22). *Newsweek, 105* (16), 10.
[23] Barney, E. C., Mintzes, J. J., & Yen, C. F. (2005). Assessing knowledge, attitudes, and behavior toward charismatic megafauna: The case of dolphins.*The Journal of Environmental Education*, *36*(2), 41-55.

conservation education and the term ‘environmental education’ was becoming more standardized. These early inquiries are the roots of modern day EE.[24]

By the 1960s, however, EE had support in the form of the National Environmental Policy Act of 1969, which encouraged the “understanding of…ecological systems on natural resources important to the Nation”.[25] Shortly thereafter, the National Environmental Education Act of 1970 was passed, which created an Office of Environmental Education (although the office was eliminated by congress six years later). The first ever Earth Day was held that same year, followed by a rapid onset of EE efforts. Environmental education began its canonization in the late 1970s with the formation of the North American Association for Environmental Education (NAAEE), the establishment of the first peer reviewed journal of environmental education, and the development of the first ever set of goals, objectives, and guidelines for constructing EE programming by the United Nation’s Intergovernmental Conference on Environmental Education.[26] By the 1980s, EE programming had been in place long enough that research projects on the outcomes and efficacy of EE were able to be conducted. The NAAEE also incorporated statewide EE organizations at that time.

The EE momentum picked up even more speed in the 1990s, when Congress passed the National Environmental Education Act, the EPA instituted an Environmental Education Training Program, EE curricula worldwide began to shift its focus towards

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[24] Palmer, J. (2002). *Environmental education in the 21st century: Theory, practice, progress and promise*. Routledge.
[25] McCrea, E. (2006). *The roots of environmental education: How the past supports the future*. Environmental Education and Training Partnership: University of Wisconsin-Stevens Point.
[26] Tbilisi Intergovernmental Conference on Environmental Education. (1978). *Toward an action plan: A report on the Tbilisi Conference on Environmental Education* (Paper developed by the FICE Subcommittee on Environmental Education). Washington, DC: U.S. Governmental Printing Office.

sustainable development, and EE research started to take shape as findings were published in new EE journals.[27]

The 'modern era' of EE (2000-present) has broadened the field by including issues of ecojustice, challenges in classroom teaching, and EE resources for burgeoning technology. The advancement of the field of EE continued in recent years with many conferences and think-tanks designed for the sole purpose of EE collaboration. In present-day, environmental education is constantly undergoing review, critique, and rejuvenation as experts in the field contribute more and more ideas to more than one dozen peer-reviewed journals that focus on EE.[28] The field of EE is, in fact, so diverse now that several sub-fields of EE have emerged as stand-alone disciplines, including citizen science.[29]

Environmental education has succeeded in doing several things. Studies show that EE curricula increases environmental literacy and often literacy in the scientific inquiry process.[30] [31] Another perceived benefit of EE is improved environmental attitudes, although studies in this area have shown more correlation than causality.[32] One hypothesis of many EE researchers is that EE could indirectly increase participation in environmental stewardship, as a result of improved environmental attitudes and increased

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[27] Tilbury, D. (1995). Environmental education for sustainability: Defining the new focus of environmental education in the 1990s. *Environmental Education Research*, *1*(2), 195-212.
[28] North American Association of Environmental Education. Retrieved May 21, 2013, from http://www.naaee.net/
[29] Winther, A. A., Sadler, K. C., & Saunders, G. (2010). Approaches to Environmental Education. In *The Inclusion of Environmental Education in Science Teacher Education* (pp. 31-49). Springer Netherlands.
[30] Berkowitz, A. R., Ford, M. E., & Brewer, C. A. (2005). A framework for integrating ecological literacy, civics literacy, and environmental citizenship in environmental education. *Environmental education and advocacy: Changing perspectives of ecology and education*, 227-266.
[31] Chepesiuk, R. (2007). Environmental literacy: knowledge for a healthier public.*Environmental health perspectives*, *115*(10), A494.
[32] Meinhold, J. L., & Malkus, A. J. (2005). Adolescent Environmental Behaviors Can Knowledge, Attitudes, and Self-Efficacy Make a Difference?. *Environment and Behavior*, *37*(4), 511-532.

environmental literacy. There have been very few studies to show this is the case, but that is likely due to an incomplete development on EE methodologies and the difficulty associated with doing such a long term study involving human subjects.

Another benefit of EE is that many school teachers view it as the perfect integrating context for their curriculum, since it is so multi-disciplinary (incorporating history, math, humanities, and science).[33] Yet another advantage of EE is that students demonstrate overall better academic performance when EE is used as an integrating context. An article written by Archie attributes this finding to increased opportunities for project-based learning, repetition of thematic principles, and application to multiple types of learning styles.[34] It has also been shown that EE lends itself to curricula which naturally foster leadership qualities in students.[35]

With all of the benefits of environmental education, perhaps it is difficult to understand why it is not more present in our public school systems. Despite the interesting advantages, there are, of course, criticisms of the field as well. One criticism, as mentioned before, is that EE presents an ethical issue of placing too much value on conservation. Another criticism is that the United States public school system has enough problems as it is – teachers struggle to fit their curricula within state-driven performance standards, standardized testing requires significant preparation in the classroom, and the ever-growing diagnosis of behavior and learning disorders presents

[33] Lieberman, G. A., & Hoody, L. L. (1998). Closing the Achievement Gap: Using the Environment as an Integrating Context for Learning. Executive Summary.
[34] Archie, M. (2003). *Advancing Education through Environmental Literacy*. Alexandria, VA: Association for Supervision and Curriculum Development.
[35] The National Environmental Education and Training Foundation. (2000, September). *Environment-Based Education: Creating High Performance Schools and Students.* Washington, DC: National Environmental Education and Training Foundation.

additional challenges to teachers.[36] It is difficult to fathom tackling all of these issues as a teacher while still incorporating EE in classroom and outreach opportunities.

It is important to illustrate what environmental education looks like, because it is now a very diverse discipline and can take on many forms. Content-wise, EE covers topics ranging from pollution and renewable energy, to species conservation and animal adaptations. Environmental education can be taught in a classroom, just like history, language arts, or mathematics. However, EE lends itself particularly well to outdoor teaching and hands-on projects. Sometimes EE is executed as a fieldtrip, while sometimes guest speakers and outreach organizations lend perspective to schools incorporating EE.[28] Since EE is derived from environmental science (including biology, ecology, and geology), the scientific method is often used in the teaching of environmental concepts. EE's connection to the humanties – such as world cultures and fine arts – makes EE a good candidate for performance and expressive opportunities. EE also manifests is ways that are independent of formal education. Conservation institutions, such as zoos, aquariums, and botanical gardens, often incorporate EE into exhibit interpretation.[37] For example, just about every zoo in the world uses signage at animal exhibits as a passive way of providing information to visitors. This signage usually gives information about a given animal's geographic range, diet, predators, and conservation status (common, threatened, vulnerable, endangered, or extinct in the wild).[38] Environmental education is as diverse as it is dynamic, and in recent years a

[36] Jickling, B. (2007). If environmental education is to make sense for teachers, we had better rethink how we define it!. *Canadian Journal of Environmental Education (CJEE)*, *2*(1), pp-86.
[37] de White, T. G., & Jacobson, S. K. (1994). Evaluating conservation education programs at a South American zoo. *The Journal of Environmental Education*,*25*(4), 18-22.
[38] Andersen, L. L. (2003). Zoo education: from formal school programmes to exhibit design and interpretation. *International Zoo Yearbook*, *38*(1), 75-81.

particular subfield of EE – citizen science – has received an abundance of attention from conservationists and environmental educators alike.

*Citizen Science*

EE has, in fact, split into several subfields which all still have goals of environmental literacy and positive environmental attitudes. Citizen science is one such example of this. Citizen science is often defined as any scientific project where professional scientists or researchers collaborate with volunteers in order to answer real-world (and often large-scale) questions.[39] These researchers may come from public or private universities, nonprofit organizations, or governmental agencies. Volunteers span across many demographic groups, including both children and adults. Citizen science is not restricted to studies in the field of conservation ecology, however, the nature of ecological research lends itself particularly well to citizen science and so the majority of citizen science projects in the United States do study topics in conservation ecology.

Most sources agree that the oldest example of citizen science is the Audubon Society's Christmas Bird Count, which began in 1900. The Christmas Bird Count (CBC) began as a one-day wildlife census, which employed the help of citizens across the nation. The original goal was to "capture an early winter snapshot of bird populations over many decades and provide birders with an enjoyable social birding experience".[40] The data collected has been used to heighten scientists' understanding of migration

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[39] Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience*, *59*(11), 977-984.

[40] "Christmas Bird Count". Retrieved May 22, 2013, from http://birds.audubon.org/sites/default/files/documents/cbc_one_pager_2012-10-5-12.pdf

patterns, breeding behaviors, and overall population health. The CBC was likely the first scientific project that had goals reaching beyond the scope of gathering data; the CBC's goals transcended science and leapt into the field of education. Although the CBC can be credited with starting a new idea in science, citizen science did not catch on until nearly one hundred years later. In present day, there are hundreds of citizen science projects the world around – and over one hundred in the United States alone – but the majority of the projects had yet to exist before the 21st century.

So what happened around the turn of the 21st century that inspired people to jump on the citizen science bandwagon? Most would probably credit the increase in citizen science opportunities to the 'Digital Revolution'.[41] Although the Audubon Society created a functional and successful way to incorporate citizens into data collection, their success might be attributed to the fact that birding requires little more than a pair of binoculars, a notebook, and writing implement. It is possible many scientists may have been interested in utilizing citizen science during the 20th century, but were unable to due to limits in technology. With the revolution of the internet, software development, and multimedia communications, it seems as though citizen science has become easier to execute. Indeed, today it would be difficult to find a citizen science project that did not integrate computerized technology into the project. Technological advancements since the 1980s have improved the functionality and efficiency of citizen science in several ways. First of all, digital technology has streamlined the process of data collection and made it more user-friendly. For example, The Wildlab has developed its own smart phone dichotomous key applications which volunteers may use to identify urban

[41] Silvertown, J. (2009). A new dawn for citizen science. *Trends in ecology & evolution*, *24*(9), 467-471.

wildlife.[42] With just a few clicks, volunteers are able to submit a data entry which includes the identification of a bird, time, location, and weather conditions. What can now be done quickly from a hand-held electronic device used to require a longer paper trail and more specialized training. Computerized technology has also improved data submission. Imagine the first years of the Christmas Bird Count. Project coordinators must have needed to meticulously go through hundreds, if not thousands, of hand-written bird observations from their participants. Now, the CBC has its participants submit their bird data online, where the data is then automatically compiled into one database. Advances in software development have made the process of data analysis less of an undertaking. Even the simplest spreadsheet software can streamline computing and sorting through data from hundreds of participants. Computerized technology has even improved the way that projects are advertized to the public, the way project findings are disseminated and shared with the public, and the way project outcomes are evaluated.[43] Advancements in technology during the 'Digital Revolution' not only made citizen science more achievable, it made citizen science more useful to researchers as well.

Although the first and longest-running citizen science project is based in the United States, it should be noted that researchers in Europe – and especially the United Kingdom – helped to create a rich tradition of citizen science starting in the 1930s. In 1932, the British Trust for Ornithology was founded "with the express purpose of harnessing the efforts of amateur birdwatchers for the benefit of science and nature conservation".[42] This initiative yielded over thirty million records of over 27,000 species

[42] The Wildlab. Retrieved May 15, 2013, from http://www.thewildlab.org
[43] Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S., & Crowston, K. (2012). The future of citizen science: emerging technologies and shifting paradigms. *Frontiers in Ecology and the Environment*, *10*(6), 298-304.

in the United Kingdom, which are largely thanks to the efforts of citizen volunteers. In 2012, another important contribution to the field of citizen science came out of the UK when the UK Environmental Observation Framework was commissioned to create a set of guidelines for creating, executing, and evaluating CS projects.[44] This was an important first step in encouraging CS projects to standardize the process of citizen science by researchers globally.

Citizen science is not limited to projects focused on ecological topics. There are several citizen science projects dealing with celestial and meteorological studies. For example, Citizen Sky began in 2009, with the mission of using volunteers to help make observations about a mysterious star called epsilon Aurigae.[45] Another study called the Citizen Weather Observer Program is exactly what it sounds like – a database of volunteer-contributed weather observations which can then be used by scientists over the long term in order to draw trends in climate change.[46] Many areas of science can utilize citizen science – as long as specialized skills can be trained, or are not needed. It is for this reason that one does not hear of too many CS projects in the field of physics or chemistry, which often depend on specialized equipment and materials.

Environmental sciences yield themselves particularly well to citizen science because observations are often required to be made outside, and not in a lab.[47] This is not to say that every citizen science project is done in the field. In fact, a very interesting CS

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[44] Tweddle, J.C., Robinson, L.D., Pocock, M.J.O. & Roy, H.E (2012). *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. Natural History Museum and NERC Centre for Ecology & Hydrology for UK-EOF.
[45] Citizen Sky. Retrieved May 21, 2013, from http://www.citizensky.org
[46] Citizen Weather Observer Program. Retrieved May 21, 2013, from http://wxqa.com/
[47] Dickinson, J. L., Zuckerberg, B., & Bonter, D. N. (2010). Citizen science as an ecological research tool: challenges and benefits. *Annual review of ecology, evolution, and systematics*, *41*, 149-172.

project that volunteers can participate in from the comfort of their own homes is called Killer Whale Tracker. Hydrophone recordings from the different parts of the Salish Sea are posted on the project's website, and volunteers can listen to recordings and record online when they hear whale vocalizations. This data helps scientists keep track of where whales migrate during different parts of the year.[48]

Ecology has its early roots in naturalist observations. Before ecological methodologies were developed and tested, scientists learned about nature by simply recording observations over time and formulating trends. In modern day, we have advanced technologies to help us gather even more specific data, but that does not mean that early ecological observations should be overlooked. Charles Darwin revolutionized one of the most integral concepts to ecology and biology in his 1859 book *On the Origin of Species*[49], primarily by acting as a naturalist. Observations in nature played no small part in the formulation of the concept of natural selection, which some would credit as a foundational concept to conservation ecology. Even though modern technology has filled in some of the gaps in ecological research, there is still a niche for observational fieldwork – especially when it involves utilizing volunteers for data collection.

Citizen science is a unique tool for conservation because it is utilized by many conservation stakeholders. While some tools are only used by conservation researchers (eg. mathematical modeling, remote sensing) and some tools are primarily used by other stakeholders (eg. advocacy, policy), citizen science bridges the gap between those tools. It is used as a direct tool for conservation, where scientists can gather more data across a larger geographic range and use this data to make conservation recommendations or

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[48] Salish Sea Hydrophone Network. Retrieved May 21, 2013, from http://www.orcasound.net/
[49] Darwin, C. (2009). *The origin of species by means of natural selection: or, the preservation of favored races in the struggle for life*. W. F. Bynum (Ed.). AL Burt.

decisions. Citizen science is also used as an indirect tool, within the context of educating program participants as a means of encouraging them to advocate for conservation.[50]

Why are so many ecologists – especially those with an agenda of conservation – choosing to utilize citizen science as a means of collecting data? As established earlier, the technology exists to do so, data can be collected on a vast geographic scale, and the sheer number of participants increases replication. But a look into the goals and objectives of citizen science projects, past and present, reveals more. Many projects, including the Christmas Bird Count, include clauses in their objectives that are not strictly reflective of the scientific agenda. As seen earlier, the CBC wishes to provide enjoyable birding experiences to its participants. Another current CS project – The Lost Ladybug Project – has scientific goals of mapping species distribution, but they claim that they have a goal to "help children become confidant and competent participants in science, identifying personally with science, so that we develop a generation of adults who are engaged in scientific discussions, policy, and thinking."[51] The Lost Ladybug Project is not unusual in including goals involving environmental stewardship and literacy. In fact, many CS projects that exist in the United States today incorporate some sort of education or outreach objective. Another example is FrogWatch (a CS project run by the Association of Zoos and Aquariums), which is concerned with monitoring frog populations around the world while allowing "individuals and families to learn about the wetlands in their communities".[52] Some CS projects even have specific conservation advocacy goals, such as Plants of Concern – a program run by the Chicago Botanic

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[50] Cohn, J. P. (2008). Citizen science: Can volunteers do real research?.*BioScience*, *58*(3), 192-197.
[51] Lost Ladybug Project. Retrieved May 20, 2013, from http://www.lostladybug.org
[52] Frogwatch. Retrieved May 29, 2013, from http://www.aza.org/frogwatch

Garden, which uses its observations to monitor the spread of invasive plant species. One of their objectives is to "train volunteers as citizen scientists to monitor rare plant populations and become conservation advocates".[53]

While many of these citizen projects seem to have added their educational or conservational goals as an afterthought (or as a secondary goal), a few of them seem to have focused the entire project around the benefits provided to the participants. Wildlife Sightings – a program that has been around since 2009 – is concerned only with natural history and claims its goal is to "organize & publish nature sightings for enjoyment [and] education, and [to] contribute to citizen science".[54] As citizen science becomes more useful to scientists, it is also becoming more useful to educators and citizens. It seems like the earliest citizen science projects were mostly created to benefit scientists, but as of late more and more projects are incorporating goals of educating the public. Is this an indicator of better marketing, or are scientists now really concerned with the citizens' outcomes as well as their own? It is possible that both of these options are being realized. While a conservation ecologist's primary goal is to do viable, productive research, it is not uncommon to find conservation ecologists who are supportive of education as a conservation tool. If they can accomplish both of these things with citizen science, then it seems like many would be in favor of it. Advertizing a CS project's educational goals would also better market a particular project to the public. After all, why would citizens choose to participate in a CS project if there was nothing to gain from it? Surely some citizens may choose to participate in citizen science for purely altruistic reasons (i.e. they want to help), but it is likely that there would be higher recruitment rates to citizen

[53] Plants of Concern. Retrieved May 22, 2013, from http://www.plantsofconcern.org
[54] Wildlife Sightings. Retrieved May 23, 2013, from http://www.wildlifesightings.net

science projects if there was something 'in it' for the citizens as well – such as learning about an interesting organism, increasing scientific literacy, etc.[55] Whether a scientist creates educational goals for marketing reasons or not, the records show that there are now more citizen science volunteers than ever before, and that growth does not yet show signs of waning.

Despite the benefits of citizen science to both volunteers and scientists, citizen science is not without flaws. By far the most criticized aspect of citizen science projects is the lacking methods for ensuring accuracy in data collection. It is expected that scientists would be concerned for the integrity of the latest research in any given field. When citizen science started gaining popularity twenty years ago, many people were worried that untrained scientists would be unable to accurately record data. This was especially a concern with projects that involve identifying organisms down to the genus and species level out in the field. In some cases, identifying an organism might be easy for even a child – for example, if a project involved tallying 9-banded armadillos on parcels of land. There is only one species of armadillo present in the United States, and armadillos are fairly unique (charismatic, even) creatures – so one need not worry about mis-identifying them. However, a great deal of citizen science projects revolve around properly identifying insects, such as in the case of BeeHunt. This CS project requires participants to ID bees – a difficult task for even a trained entomologist. Even with a very high resolution photo of a bee, it can be difficult to identify as there are thousands of

[55] Raddick, M. J., Bracey, G., Gay, P. L., Lintott, C. J., Murray, P., Schawinski, K., ... & Vandenberg, J. (2010). Galaxy zoo: Exploring the motivations of citizen science volunteers. *Astronomy Education Review*, *9*, 010103.

species native to the United States.[56] Another criticism of citizen science is that participation is not randomized.[57] A researcher might be looking to get a diverse spread of participants from across a geographic range and turn to citizen science to accomplish this. In reality, CS projects often end up with participant clustering in just a few areas. Sometimes this happens because of uneven recruitment efforts. A university is a great source of eager students looking to get some experience in data collection, and CS project coordinators often market their projects to University student bodies.[58] The upshot is that data might reflect only a few specific places instead of being evenly distributed across the full project range.

Luckily, the development of citizen science as its own unique discipline over the last twenty years has led to canonization of the field. Researchers from conservation ecology, science education, nonprofit management, and sociology have come together to evaluate the techniques used in citizen science projects and the outcomes. There are now more than a dozen peer-reviewed journals that publish research on the practice of citizen science, including Frontiers in Ecology and the Environment, The International Journal of Citizen Science, and Ecology and Society. The findings of this research are used to address the criticisms mentioned earlier and ultimately make the discipline of citizen science more efficient, more functional, and more beneficial to both those who coordinate and those who participate in CS projects.

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[56] "Native Bees of North America". Retrieved May 23, 2013, from http://bugguide.net/node/view/475348

[57] Oberhauser, K., & Prysby, M. D. (2008). Citizen science: creating a research army for conservation. *American Entomologist*, *54*(2), 103-104.

[58] Oberhauser, K., & LeBuhn, G. (2012). Insects and plants: engaging undergraduates in authentic research through citizen science. *Frontiers in Ecology and the Environment*, *10*(6), 318-320.

Many researchers in this process have struggled to come up with ways to hone the methods of citizen science. However, these pioneers have still stumbled upon some helpful revelations in the process. One of the first publications addressing citizen science was written by Mumby et al. in 1995. Volunteer divers performed quantitative reef-sampling techniques (including organismal identification), and the authors found the data had a wide range of accuracy – from 52-70%.[59] Since then, several other researchers have assessed the accuracy of volunteer-collected data by comparing data of amateurs to professionals. Galloway et al. trained students in grades three through ten in some basic forest ecology techniques (eg. measuring diameter at breast height), and then sent students out on a data-collecting spree on previously measured trees. Overall, there was a problem with selective sampling, but the measurements were closely matched to those of the experts.[60] A final example of this CS assessment technique was explored by Delaney et al. in 2007. Students in grades three through seven were provided with training to identify native and invasive species of crabs, and they were able to do so with up to 95% accuracy.[61] The bottom line of all the studies measuring validity of citizen science (and the accuracy of the data collected) seems to be that with proper training and simple guidelines, volunteers of any age can be entrusted with simple tasks that gather data. As long as the scientists are entrusted with evaluating and manipulating the data, a small amount of uncertainty is no cause for concern. The key to creating a functioning citizen science project is to ensure that the tasks you are entrusting to your volunteers are

[59] Mumby, P. J., Harborne, A. R., Raines, P. S., & Ridley, J. M. (1995). A critical assessment of data derived from Coral Cay Conservation volunteers. *Bulletin of Marine Science*, *56*(3), 737-751.
[60] Galloway, A. W., Tudor, M. T., Haegen, W., & VANDER, M. (2006). The reliability of citizen science: a case study of Oregon white oak stand surveys.*Wildlife Society Bulletin*, *34*(5), 1425-1429.
[61] Delaney, D. G., Sperling, C. D., Adams, C. S., & Leung, B. (2008). Marine invasive species: validation of citizen science and implications for national monitoring networks. *Biological Invasions*, *10*(1), 117-128.

objective, simple, and easily understood.  Citizen science volunteers ought to take the place of scientific instruments – not the scientist.[62]

In addition to quantitatively computing the accuracy of volunteer-collected data, researchers have relied on qualitative assessments to shed light onto CS evaluation.  For example, staff at the Cornell Laboratory of Ornithology read through hundreds of letters written by participants in Project FeederWatch.  Staff extracted useful information from the letters that indicated the participants' level of science literacy.  Ultimately they concluded that citizen science appeals to participants who are already somewhat interested and literate in the topic at hand, and therefore the educational impact of such a project is not as dramatic as one would hope.[63]  Other ways researchers have experimented with evaluating educational impacts include interviews, surveys, and pre- and post-tests.

Up until recently, most papers on the topic of citizen science were written to address the issues of accuracy in data collection.  In other words, most research was biased towards the concerns of the scientists.  Recently, however, more and more papers have been coming out addressing the opposite perspective.  Instead of just evaluating how project coordinators can make the citizen science experience better for the scientist, now they are evaluating how they can make the citizen science experience better for the volunteer.  Since it has been established that citizen science provides more than just data for scientists, it is important to address those other outcomes.  Most of these outcomes include scientific literacy, environmental stewardship, advocacy, or environmental

[62] Wright, Alex. "Managing Scientific Inquiry in a Laboratory the Size of the Web." *The New York Times*. N.p., 27 Dec. 2010. Web.
[63] Trumbull, D. J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education*, *84*(2), 265-275.

attitudes.  Couvet et al. found that citizen science participants disseminate the knowledge they gain from CS projects, thus contributing to overall increased scientific literacy in society.[64]  Another study found that scientists and volunteers are not the only people who benefit from citizen science – STEM (science, technology, engineering, and mathematics) educators and society at large also benefit from CS.[65]

Many researchers who are unaffiliated with the CS projects they are evaluating have acknowledged that these projects might benefit from incorporating an evaluation program into the CS protocol.  Program evaluation is a systematic method of collecting information about a particular program (such as an EE project) that allows the project coordinator to improve the project.[66]  For example, program evaluation could consist of a survey to CS participants after data collection was completed.  The survey could reveal a number of things about the participants' experience – such as difficulties they had in understanding the protocol, or appreciation they felt from program incentives.  The CS program coordinator could then use this information to change the format of the program – including enhancing the protocol instructions and increasing the number of program incentives.  Program evaluation is a feedback loop which should ultimately help project coordinators continuously hone CS projects.  Bonney et al. draws attention to the need for more evaluation programming in citizen science, asserting that the social science method

[64] Couvet, D., Jiguet, F., Julliard, R., Levrel, H., & Teyssedre, A. (2008). Enhancing citizen contributions to biodiversity science and public policy.*Interdisciplinary science reviews*, *33*(1), 95-103.
[65] Raddick, M. J., Bracey, G., Carney, K., Gyuk, G., Borne, K., Wallin, J., ... & Planetarium, A. (2009). Citizen science: status and research directions for the coming decade. *AGB Stars and Related Phenomenastro 2010: The Astronomy and Astrophysics Decadal Survey*, 46P.
[66] Jordan, R. C., Ballard, H. L., & Phillips, T. B. (2012). Key issues and new approaches for evaluating citizen-science learning outcomes. *Frontiers in Ecology and the Environment*, *10*(6), 307-309.

of evaluation is not very well understood by scientists and that incorporating evaluation can be one of the biggest challenges to citizen science.[67]

As more and more scientists incorporate citizen science into their research, more and more questions about the strengths, weaknesses, and future of citizen science arise. Researchers publishing on the discipline of citizen science are developing novel questions, such as 'Do citizen science participants alter their behavior in favor of environmental stewardship as a result of CS?'[68], 'What are the demographic trends among CS participants?'[56 69], and 'Does incorporating the latest technologies into CS projects hinder or help project outcomes?'.[70] As the field of citizen science becomes more diverse, stakeholders from increasingly varied fields take interest in citizen science's future. Citizen science now sparks the interest of politicians, teachers, parents, grant writers, and administrators – all because of the potential this innovative programming presents to the public. In many cases, the real link between stakeholders is a vested interest in conservation education.

Having established that citizen science is useful to ecological researchers for studying broad-scale topics and useful to citizens for providing environmental education and volunteer opportunities, it is essential that the field of CS is developed to become

[67] Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. *Online Submission*.
[68] Jordan, R. C., Gray, S. T., Howe, D. V., Brooks, W. R., & Ehrenfeld, J. G. (2011). Conservation education and citizen science: using an invasive plant case study to highlight issues of practice. *Conservation Biology. doi*, *10*.
[69] Pandya, R. E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment*, *10*(6), 314-317.
[70] Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., ... & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*,*10*(6), 291-297.

more collaborative and more multidisciplinary.[71] [72] One area of citizen science that has not been thoroughly explored is trends in citizen science coverage. Specifically, very few researchers have taken note of which taxonomic groups of organisms have been historically utilized in citizen science projects.

Another gap in the research of the practice of citizen science is which topics in conservation ecology receive the most attention. It is important to find out if there are gaps in taxa and topic coverage so that we can develop the potential of citizen science to address more pressing issues. If these gaps are brought to the attention of citizen science project coordinators and conservation ecologists, perhaps the field of citizen science will rise up to the challenge of utilizing citizen science in areas where there is more need for this collaborative and participatory tool.

The research that has addressed the above issues is limited. Two studies discussed using birds in citizen science and suggested that CS projects which are ornithological in nature are successful, perhaps because of the long history of birding as a past-time and because birding in citizen science has been around so long.[73] [74] Perhaps the natural history of different taxa poses certain limitations to citizen science. For example, it is not difficult to understand why a CS project conducting research on snakes might be less viable than one on butterflies. Snakes are unpopular to (and even feared by) a large

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[71] Chandler, M., Bebber, D. P., Castro, S., Lowman, M. D., Muoria, P., Oguge, N., & Rubenstein, D. I. (2012). International citizen science: making the local global. *Frontiers in Ecology and the Environment*, *10*(6), 328-331.
[72] Switzer, A., Schwille, K., Russell, E., & Edelson, D. (2012). National Geographic FieldScope: a platform for community geography. *Frontiers in Ecology and the Environment*, *10*(6), 334-335.
[73] Snäll, T., Kindvall, O., Nilsson, J., & Pärt, T. (2011). Evaluating citizen-based presence data for bird monitoring. *Biological conservation*, *144*(2), 804-810.
[74] Sullivan, B. L., Wood, C. L., Iliff, M. J., Bonney, R. E., Fink, D., & Kelling, S. (2009). eBird: A citizen-based bird observation network in the biological sciences. *Biological Conservation*, *142*(10), 2282-2292.

percentage of the public[75], even if this fear is unjustified and based in myth. Since charismatic megafauna plays a role in conservation-based decisions, it can be proposed that charismatic megafauna are favored in citizen science projects.

It is difficult to get conservation ecologists to agree on what the 'big topics' are in their field. They would all likely agree that the 'big topics' today are not the same as the 'big topics' fifty years ago, however. This is partly because ecology is an evolving field, with shifting paradigms, and partly because funding influences scientists' research priorities. However, if we look at what researchers have identified in recent years as the biggest threats to biodiversity, we can use that as an indicator of what the 'big topics' in conservation ecology are. Salafsky et al. identified wildlife pathogens (such as Chestnut Blight and Chytrid fungus) as a major threat to biodiversity over ten years ago.[76] In 2008 Salafsky followed up with a more detailed classification of the threats to biodiversity, including (but not limited to) pollution, habitat destruction, invasive species, and geological disturbances.[77] A very recent paper on new threats to biodiversity includes specific advances in technology, such as use of antimicrobial peptides, but also references a not-so-new threat – aquaculture.[78] If one was not already convinced that global climate change is one of the biggest threats to conservation today, one need only look at the increase in publications and nonprofit organizations centered around global climate

[75] Wilson, E. O. (1984). *Biophilia*. Harvard University Press.
[76] Salafsky, N., Margoluis, R., Redford, K. H., & Robinson, J. G. (2002). Improving the practice of conservation: a conceptual framework and research agenda for conservation science. *Conservation biology*, *16*(6), 1469-1479.
[77] Salafsky, N., Salzer, D., STATTERSFIELD, A. J., HILTON-TAYLOR, C. R. A. I. G., Neugarten, R., BUTCHART, S. H., ... & Wilkie, D. (2008). A standard lexicon for biodiversity conservation: unified classifications of threats and actions. *Conservation Biology*, *22*(4), 897-911.
[78] Sutherland, W. J., Bardsley, S., Clout, M., Depledge, M. H., Dicks, L. V., Fellman, L., ... & Watkinson, A. R. (2012). A horizon scan of global conservation issues for 2013. *Trends in ecology & evolution*.

change that have cropped up in the last ten years.[79] [80] An assessment of current literature in conservation ecology journals may be the best way to determine which topics are the most pressing and worthy of funding. The most frequently researched topics in conservation ecology journals seem to be: global climate change, phenology, water/air quality, disease ecology, species invasions, biodiversity, natural history (including life history data), and population dynamics.[81]

If these topics are indicators of the biggest threats to biodiversity, then one can assume research on these topics would receive priority in funding. Citizen science projects in the field of conservation ecology should then also reflect these topics. If they are not, then recommendations will need to be made. Further, citizen science projects with an ecological (but not conservational) focus may have some overlap with these topics (such as invasive species), but may also address other issues that only have indirect links to conservation.

## Project Logistics

### *Research Questions & Hypotheses*

Having proposed the need for citizen science as a tool for conservation, the following research questions were asked: 1) What taxa are not yet (or minimally) represented in ecological citizen science projects?, 2) What areas of conservation ecology are not yet (or minimally) represented in citizen science projects?, 3) Are

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[79] Brooks, T. M., Mittermeier, R. A., da Fonseca, G. A., Gerlach, J., Hoffmann, M., Lamoreux, J. F., ... & Rodrigues, A. S. (2006). Global biodiversity conservation priorities. *science*, *313*(5783), 58-61.

[80] Parmesan, C. (2006). Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics*, 637-669.

[81] Carmel, Y., Kent, R., Bar-Massada, A., Blank, L., Liberzon, J., Nezer, O., ... & Federman, R. (2013). Trends in Ecological Research during the Last Three Decades–A Systematic Review. *PloS one*, *8*(4), e59813.

current citizen science projects congruent with what scientists identify as the most pressing environmental concerns facing biodiversity?, and 4) What recommendations can be made to scientists who would like to embark on incorporating citizen science into their conservation research plans? Based on current literature and early anecdotal evidence, it was predicted that reptiles, amphibians, macroinvertebrates, and microorganisms are underrepresented in CS projects, and that there is a discrepancy between the topics addressed in CS projects and the topics identified as 'most pressing' to conservation ecology.

*Overview of Methods*

The answers to these questions were identified using two techniques. First, a great deal of information was gathered from online resources on 150 citizen science projects currently existing in the United States. This information included where the project is based (meaning where the project director or coordinators work from), when the project began, who hosts the project, and which taxonomic groups are studied. In addition, conservation ecology topics studied in these citizen science projects were identified. This data was almost always readily available by performing a quick assessment of the CS projects' web pages. Additionally, the Cornell Laboratory of Ornithology was a useful source of information, as they have constructed an online database of citizen science projects around the country. This database is called "Citizen Science Central", as is freely accessible to anyone with access to the World Wide Web.[82] Data acquired from CS project websites and "Citizen Science Central" were compiled

[82] Citizen Science Central. Retrieved May 25, 2013, from http://www.birds.cornell.edu/citscitoolkit

into a spreadsheet (see appendix). Citizen science projects that did not have a connection to an ecological topic were not included in the spreadsheet.

In addition to extracting data from online resources, an online survey was created and distributed to all 150 citizen science projects identified in the United States. This online, twenty-five question survey was sent to the coordinators or managers of these projects. The survey posed questions regarding project evaluation, participant base, project goals, and feedback from project participants (see appendix). Out of 150 citizen science projects, it was projected that one third of the survey recipients would respond to the survey. Indeed, exactly fifty-two CS project coordinators provided feedback – about 35%. Survey responses were assessed and displayed visually or graphically wherever possible. Qualitative responses were read and used for determining trends in citizen science, as identified by project coordinators.

## CHAPTER 2 – RESULTS & DISCUSSION

**Results**

Based on information gathered from 'Citizen Science Central' and individual project webpages, dates of project initiation were compiled. However, many projects (about 1/3) did not have this information available. Out of the ninety-six citizen science projects that did have this information available, 57% were initiated between the years 2000 and 2009. If the most recent years of 2010-2013 are included in this assessment, then since the year 2000, sixty-five projects have been created. Those sixty-five projects represent 69% of the projects which had this information available. Citizen science projects remained sparse until the 1990s, when an almost exponential increase in project establishment was noted. An exponential line-of-best-fit was added to Figure 1 and shows that the data very nearly fits this curve.

*Taxonomic Preference*

It has already been documented that birds have historical been a popular focal organism in citizen science projects, for many reasons. An assessment of taxonomic breakdown of citizen science projects in the United States confirmed that birds are still the most widely used taxa in CS projects. Forty-nine out of 150 projects study birds – representing about one third of all citizen science projects studied. However, it is important to note that many projects – about one third – study more than one taxonomic group. This means that the 33% of projects studying birds were not exclusively studying birds – some studied birds in conjunction with other organisms. The combination of birds, insects, and plants represented about 50% of the citizen science projects that studied biota. The other 50% studied all other biotic groups, with microorganisms, fungi, and fish representing the least studied groups. Figure 4 shows a pie chart representing this distribution. A small percentage (12.7%) of survey participants claimed to study only abiotic parts of the environment (pH, temperature, soil chemistry, etc.). There were almost as many CS projects which study both biota and abiota as there were projects which strictly study biota.

In order to ascertain whether or not certain taxa have been trending in recent years, projects initiated in the last ten years were scrutinized. Information on both topics and taxa studied from these projects was gathered from both survey data and project webpages. The results, displayed in Figure 6, do not show any trends. The taxonomic breakdown of the last ten years of citizen science do not show an increased preference for any taxonomic group, nor do they show a decreased preference for any taxonomic group. The distribution appears to be random. However, if one looks at the longest-running citizen science projects – the projects that were established prior to the Digital Revolution (1995) – a clear preference for birds emerges. Another way to look at trends in taxonomic groups studied in citizen science projects is to compare early CS projects with more recent CS projects. Figure 7 illustrates how the taxonomic distribution has changed from the 20$^{th}$ century to the 21$^{st}$ century. Birds and abiota were the most heavily represented study subjects early on, but in recent years study subjects are more evenly distributed among biotic groups, with a much greater representation of plant-centric projects than before.

*Topics of Study*

Survey participants were given a list of conservation ecology topics and asked to check any that apply to their CS project. They were also given an option to specify "other". These topics included biodiversity, invasive species, global climate change, resource management, disease ecology, water/air quality, population dynamics, phenology, or life history data. A surprising result was that nearly all survey respondents chose more than one topic.

The topic of biodiversity was the most selected, receiving selection by 15% of survey respondents. However, most of the topics received about equal votes. The only notable outcome of that question was that disease ecology and topics identified as "other" (such as environmental health) appear to receive very little attention in CS projects. Disease ecology was represented by only 5% of surveyed projects. These results are displayed in Figure 5.

*Beyond Topics & Taxa*

*Geographic Distribution*

Figure 2 show the geographic distribution of citizen science projects in the United States, and figure 3 shows a closer look at just the continental U.S. The blue markers indicate a city where only one project is based. The yellow markers indicate a citizen science 'warm spot', where two to three projects exist. The red markers are citizen science 'hot spots', where four or more projects take place.

The vast majority of map markers (~seventy-five) are blue, while only twenty are yellow and four are red. The citizen science 'hot spots' are located in Ithaca, New York, Tremont, Tennessee, Tuscon, Arizona, and San Francisco, California. The hot spots in Ithaca, Tremont, and Tuscon are relatively isolated from other citizen science hubs, while San Francisco is within close proximity of several other citizen science hubs in California.

The map also shows several ‘gap’ areas in the United States where there are no hubs of citizen science currently. It is important to note that this map does not show where participants are located – only where the coordinating organization is located. These gaps areas occur in the North-Central and South-Central regions of the United States. Specifically, the states of Montana, North Dakota, South Dakota, Wyoming, Nebraska, Nevada, New Mexico, Oklahoma, Arkansas, Louisiana, Mississippi, Alabama, Kentucky, West Virginia, Ohio, Michigan, Connecticut, Rhode Island, Delaware, and Alabama are completely devoid of citizen science hubs.

One survey questions asked CS project coordinators whether their project was restricted to a particular region of the United States, or if anyone, nationwide, could participate. The results showed that 50% of those projects were restricted to a particular region (either a city, state, or other defined region) while 50% were open to participants located anywhere in the United States.

*Program Evaluation*

Citizen science program coordinators were asked several questions regarding their use of program evaluation in their citizen science projects. Among these questions, they were asked if they completed any kind of evaluation programming at the completion of their data collection season. The results showed that 60% do use some kind of evaluation, which mostly comes in the form of participants surveys. 25% do not use any kind of program evaluation, and 15% did not know if they used any kind of program evaluation.

As a follow-up to the questions on evaluation, survey participants were asked to report examples of praise and criticism they received from project participants. These examples may have been received as the result of their evaluation programming, or they have been given to the project coordinators unsolicited. The praise and criticisms were grouped into different categories. Figures 8 and 9 sum up the findings. The most widely received praise from CS project participants fell into the category of educational value. This included comments that participants enjoyed learning about the organisms studied or about the ecological basis for the project. Praise also came in the form of recognizing the recreational merit of CS projects and recognizing the administrative functionality of the project. To a lesser extent, project volunteers acknowledged their enjoyment of 'giving back' to what they perceived as a worthy cause. About 10% of projects claimed that they have not received any praise. The most widely received criticism from CS project participants fell into the category of difficult or confusing project procedures. These complaints represented about 22% of participant complaints. Another highly represented complaint fell into the category of technical problems. This included examples of communication failures, website errors, and other IT issues. A smaller percentage of participants (7.4%) complained about not feeling connected or valued in the project due to lack of feedback.

### *Project Goals*

Survey participants were asked if their CS projects' objectives contained any reference to environmental education. More specifically, they were asked if their projects' objectives have any reference to environmental learning, environmental stewardship, or environmental attitudes. If they did have these kinds of references, they were asked to provide excerpts from project mission statements or strategic plans. Out of fifty-two respondents, only 8% claimed that their project did not have an educational goal or objective. Among the 92% of respondents who did claim goals in environmental education, the responses were evenly split between goals of environmental literacy and goals of environmental stewardship. However, many respondents admitted that these goals were not officially written down anywhere and therefore they could not provide excerpts. In fact, nearly 38% of these respondents were unable to provide proof of their EE goals when asked if their project objectives had any reference to environmental literacy, environmental stewardship, or environmental attitudes, or they simple responded "no" or "not really". The results of these survey questions show a discrepancy between perceived goals and actual goals.

### *Demographic Data*

Survey respondents were also asked about the ages of their project participants. The options they had to choose from were: pre-k/kindergarten, elementary school students (grades 1-5), middle school students (grades 6-8), high school students (grades 9-12), college/grad students, and adults/senior citizens. The data acquired reflected a very steady increase in demographics. It is important to note that almost all of the survey respondents choose more than one group.  Only 15% of projects identified pre-/kindergarten-age children as being part of their participant base, while 44% of projects utilized elementary school children as participants.  63% of projects included middle school students and 71% included high school students.  81% of projects utilized college or graduate level students, and almost all projects (94%) targeted adults for their participant base.  The demographic breakdown of project participants is show in Figure 10.

CS project coordinators were also asked about their participant retention rates. The results show that 9% of the projects retained less than 5% of their participants from one season to the next, while 19% retained up to 25%, 15% retained up to 50%, 21% retained up to 75%, and 11% retained almost 100% of their participants.  One quarter of the respondents claimed that their participant retention was unknown

The administrative demographics of the CS projects were also assessed.  Survey participants were asked about the number of paid staff members they employed versus the number of volunteer staff they had working on their projects. Of the fifty-two respondents, 25% did not have a single paid staff member, 46% had one or two paid staff members, and the rest (29%) had more than two paid staff members, but nearly all were part-time.

## Discussion

The exponential increase in citizen science projects has been attributed by many to the ‘digital revolution’ – a period of technological growth in computing, software development, and communication that started in the 1980s.[41]  The proliferation of the internet in the 1990s dramatically increased the spread of information between scientists and the public.[83] Citizen science benefited from these advancements in technology in several ways. One contribution is the use of the internet as a marketing tool. Prior to the widespread use of the internet, CS projects would have needed to rely on word-of-mouth or printed advertisements to recruit participants, which had its limitations. The internet not only serves as a platform for webpage development, but it also allows for CS projects to communicate quickly and efficiently with project volunteers via email communication. Another contribution of the digital revolution to citizen science is the development of tools to be used in data collection. Tools such as global positioning devices, digital cameras, and smart phones have made it easier for CS project coordinators to design protocols where individuals can more efficiently acquire useful data aided by the aforementioned technological tools. The digital revolution has also benefited the growth of citizen science by aiding in the process of data analysis. Data can now be submitted online, through shared documents, via smart phone apps, or directly through a CS project's website. After data has been collected, scientists now have a suite of tools available to them for analysis. Even the simplest spreadsheet application affords scientists the ability to quickly and easily make calculations with and graphically display their data – a luxury that was not available to the first citizen science project managers. The digital revolution is still in progress and will continue to improve the way CS projects are conducted, as long as scientists can think of ways to make the latest technologies applicable to their research.

[83] Nentwich, M. (2004). Cyberscience: research in the age of Internet. *Vienna: Austrian Academy of Science*.

*Taxonomic Preference*

Based on the data acquired on the representation of taxonomic groups in citizen science projects, it is clear that fish, fungi, and microorganisms are underutilized in CS research. Previous research suggests that certain taxa yield themselves particularly well to CS projects. For example, birds are popular focal subjects because they are often easily observed in nature with the right equipment, there is historic link to birding as one of America's oldest past-times, and birds can be used to study many topics of conservation ecology.[73 74] Despite there being many CS projects which study freshwater and marine habitats, there are only a few which study fish. Fish may be underrepresented because of their elusive nature, or because of the specialized skills required to measure or observe them in the wild (eg. scuba diving, fishing).[84] Fungi is perhaps underrepresented in CS research because mycology is still a developing sub-field of ecology, and scientists have not yet discovered ways to incorporate fungal observations into conservation methodology.[85] Microorganisms, such as bacteria, are obviously impossible to observe in nature with the naked eye, making them a less popular choice than larger species, which can be detected without any special equipment. However, the inability to observe them with the naked eye does not indicate that they cannot be used in the scope of citizen science. An innovative example of a CS project which studies microorganisms is Project Monarch Health – based in Athens, Georgia and established in 2006. This project seeks to study the occurrence and range of *Ophryocystis elektroscirrha*, a protozoan parasite which infects monarch butterflies in North America. In order to track the parasite, CS

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[84] Pawar, S. (2003). Taxonomic chauvinism and the methodologically challenged.*Bioscience*, *53*(9), 861-864.
[85] International Society for Fungal Conservation. Retrieved June 10, 2013, from http://www.fungal-conservation.org

project participants are asked to catch adult monarch butterflies and sample for *O. elektroscirrha* by adhering a small strip of scotch tape to the abdomen of the butterfly. The strip is then removed, placed on an index card with observational data (such as date and location of capture), and mailed to the Monarch Health laboratory for analysis. Since the protozoan parasite lyses through the abdomen of the adult monarch, an infected monarch will have parasite spores embedded in the abdominal scales.[86] This project demonstrates a really simple way to involve CS project participants in the study of microorganisms. The success of this project is partly due to the study of *O. elektroscirrha* in conjunction with a larger animal and partly due to the careful planning of the project protocol.

Figure 7 showcases how taxonomic trends in citizen science have varied from the early use of citizen science to modern day. The notable changes between the two pie-charts are the overall more even distribution of taxa in recent years and the increase in plant research in recent years. An explanation for the increase in CS projects involving plants might be found in species invasions literature. The ecological literature on weedy plants started to become more abundant during the 1990s (as evidenced by a quick literature search), and continued to develop in the 21st century. It is not a terrible leap of logic to assume that the popularity of a particular research topic would correlate to the popularity of that subject matter in CS projects. The increase in literature on invasive plants at that time would indicate that more projects were being funded at that time, and therefore plants would be more highly represented in modern CS projects than in earlier CS projects.

[86] Project Monarch Health. Retrieved June 9, 2013, from http://www.monarchparasites.org

*Topics of Study*

One might expect to see popular ecological research areas reflected in the CS project database. It is no secret that large funding sources like the National Science Foundation (NSF) have dynamic funding priorities that fluctuate as scientific literature brings to light new or neglected areas of research. For example, in 2007 the NSF initiated the Climate Change Science Program[87] which prioritized funding projects that illuminated the impacts of global climate change on multiple earth systems.[88] As scientific literature reveals new areas of potential for empirical scientific inquiry, funding priorities shift. If we assume that the selection of ecological research projects that incorporate citizen science represent a randomized sample of the entirety of ecological research projects based in the United States, then we would expect CS projects to reflect a variety of 'pressing topics' in conservation ecology. However, it was hypothesized that there would be a discrepancy between the topics addressed in CS projects and the topics identified as 'most pressing' to conservation ecology. This hypothesis was formed by taking into consideration lacking program evaluation for CS projects and recognizing the largely unrealized potential for CS projects in current literature. This hypothesis was supported upon the revelation that the topic of disease ecology is underrepresented in CS projects. This finding could be correlated with the previous finding that microorganisms are also underrepresented in CS projects. Disease ecology research spans a range of infected taxonomic groups, but the origin of these diseases is often viral, fungal, or

[87] NSF-Wide Investments for Previous Fiscal Years. Retrieved June 24, 2013, from http://www.nsf.gov/news/priority_areas/previous_fy.jsp
[88] "Climate Change Science Program". Retrieved June 24, 2013, from http://www.nsf.gov/about/budget/fy2009/pdf/38_fy2009.pdf

bacterial in nature.[89] In other words, much of what disease ecologists study would be intangible to naturalist observers, and therefore inapplicable to citizen science. However, an important part of what disease ecologists study is the affects of disease on biota, and this is a variable that often can be observed, especially with regards to wildlife disease. One example of a successful application of citizen science to disease ecology research is described in a recent publication by Dickinson et al. The authors describe the House Finch Disease Survey, which was run by the Cornell Laboratory of Ornithology from 1994 through 2004. This CS project engaged volunteers by having them document the occurrence of infected house finches at their feeders by having them look for obvious infection symptoms (red, swollen, and/or encrusted eyes).[47] This is a clear example of how seeing indicators of a disease can be as effective as seeing the disease itself. Other researchers have highlighted the potential in disease ecology for applications to citizen science,[90] which suggests that disease ecologists may want to begin collaborations with more experienced CS project coordinators.

### *Beyond Topics and Taxa*

#### *Geographic Distribution*

The geographic distribution of citizen science hosts (as shown in Figure 3) reveals several important points. Three out of four of the citizen science 'hot spots' are the result of one large funding organization acting as the host for all the CS projects in that location. One 'hot spot', however, is unique. There are nine projects that are based in

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[89] Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife--threats to biodiversity and human health. *science*,*287*(5452), 443-449.
[90] Crowl, T. A., Crist, T. O., Parmenter, R. R., Belovsky, G., & Lugo, A. E. (2008). The spread of invasive species and infectious disease as drivers of ecosystem change. *Frontiers in Ecology and the Environment*, *6*(5), 238-246.

San Francisco – sixteen if you include the greater Bay Area – and most of these projects have different host organizations. Some are run by the National Park Service, while others are coordinated by San Francisco State University or a private nonprofit organization (such as Otter Spotters[91]). Perhaps this makes sense, considering San Francisco is a relatively large metropolitan area with many resources. The other 'hot spots' in the United States are certainly in less populated areas – Tuscon, AZ, Ithaca, NY, and Tremont, TN. The sources of their CS project concentrations are the University of Arizona, the Cornell Laboratory of Ornithology, and the Great Smoky Mountains Institute, respectively. If it were not for these invested institutions, it seems unlikely that towns that size would be capable of supporting that many citizen science projects (at least at this time, when CS popularity is still growing). Why is San Francisco such a hub for citizen science? There are certainly much bigger cities, with more resources to fund citizen science. Perhaps San Francisco is an ideal location for CS projects because of its urban resources and proximity to a variety of habitats. The San Francisco Bay is itself a unique source of ecological studies, yet the Pacific Ocean, beaches, and mountains all provide more opportunities for ecological studies. Anecdotally, San Francisco has a reputation as being a more progressive geographic region when it comes to environmental conservation and advocacy. Several sources have consistently rated San Francisco as one of the 'greenest' cities in America, basing this rating on factors such as usage of public transit, % of citizens that recycle, and usage of solar energy.[92] The fact that San Francisco always appears at or near the top of these lists (in addition to nearby

[91] "Otter Spotters". Retreived June 8, 2013, from http://www.riverotterecology.org/otter-spotter-citizen-science-project.html
[92] "San Francisco Named North America's Greenest City". Retrieved June 4, 2013, from http://www.greenbiz.com/news/2011/06/30/san-francisco-named-north-americas-greenest-city

cities Oakland and Berkeley) is an indicator that the city's residents are invested in environmental conservation.  This may be this simplest explanation for why the San Francisco Bay Area is a hub for citizen science projects with goals of environmental conservation.  It is important to note that Figure 3 should not be used as an exclusive indicator of where CS participants are located.  Although the map shows where these projects were initiated (and/or where the data is assessed), participants in these projects can often come from great distances.  The proliferation of computer based technology has allowed citizens to participate in many projects from afar, and in fact most CS projects that are active today are trying to recruit participants from all over the country in order to get more randomized results.  However, it should be noted that cities which have not started their own CS projects are less likely to have citizens informed of these opportunities.  Although CS projects can advertise and recruit through the internet, there may be less opportunities for CS exposure in cities which do not have their own projects going on.

Another interesting thing to note about the geographic distribution of citizen science is that there are many gaps on the map.  Upon first glance at the map, one notices the concentration of markers on the east coast, in California, and in parts of the Midwest (Minnesota and Wisconsin).  There are a great many states which have no citizen science hubs (North & South Dakota, Montana, Oklahoma, Mississippi, Nevada, etc.).  Although people living in these parts of the country could certainly participate in nationwide projects like Monarch Health or School of Ants, the likelihood of them knowing about these projects is smaller than them knowing about projects that were based in their own 'backyard'.

Of all fifty-three survey respondents, just slightly more than half (51%) claimed that their CS project is restricted to a particular region of the United States, while the remaining 49% claim that participation is open to citizens nationwide. This indicates that there are certainly no shortages of CS projects for citizens in ‘gap areas’ to get involved with – but how people would know about these projects depends on the type of marketing the CS project directors choose to use. More research is needed to determine the effects of marketing on public participation in citizen science.

*Program Evaluation*

Program evaluation has been identified by Bonney et al. 2009 as an important and necessary component, to successful citizen science projects. However, many project coordinators remain uncertain of how to implement an effective evaluation program, since evaluation efforts are usually not formally executed in scientific investigations. Evaluation techniques usually come from the world of social science – in areas like nonprofit management, psychology, and political science. Most citizen science projects function via a top-down approach to gathering data, where the person implementing the citizen science protocol is usually a researcher or scientist who may have limited experience in the social sciences. Fortunately, citizen science is such an interdisciplinary field that it yields quite well to incorporating outside influences.[93]

Evaluation programming is needed to ensure the sustainability of any given project. The goal of evaluation is to assess project success, and figure out what can be

[93] Irwin, A. (1995). *Citizen science: A study of people, expertise and sustainable development*. Psychology Press.

done to bolster strengths and diminish weaknesses.[94] Often evaluation is accomplished by post-project surveys, interviews, focus groups, and outside consultation. In the case of citizen science, it is important to evaluate CS projects from both the scientists' and participants' perspectives. The scientists that are evaluating data collected by citizens can reflect on gaps or concerns in the data acquired, while the participants can reflect on potential difficulties with project instructions, parameters, and incentives. If evaluation is done effectively, the concerns of the participants should inform how the scientists restructure their project protocol and at the same time the concerns of the scientists should inform how participants collect data.

When survey respondents were asked about their evaluation methods, only 60% responded that they incorporated some kind of evaluation into their CS project. Many respondents were unsure if they even had an evaluation program (15%). Among respondents who claimed to not have an evaluation program, the majority (64%) claimed the reason was that they had no time or resources to implement an evaluation program. The survey responses regarding program evaluation indicate that CS projects lack a standardized method of evaluation. Survey data gathered on CS project staff informs one possible explanation for lacking evaluation programs. Many CS projects only have volunteer staff or one to two paid staff members who are responsible for running all aspects of their projects. Seeing as CS projects are interdisciplinary and require an assortment of duties (recruitment, protocol design, volunteer training, data analysis, dissemination of findings, and publication), it might be difficult for projects with limited staff to incorporate evaluation programming as well.

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[94] Worthen, B. R., Sanders, J. R., & Fitzpatrick, J. L. (1997). *Program evaluation*. Longman.

Sometimes, as part of program evaluation, CS project coordinators attempt to keep track of demographic data, such as the age, gender ratio, background, and retention of their participants. This kind of information can be useful to project coordinators for marketing their CS project in the future, as well as indicating gaps in the types of people their project is including. Twenty-five percent of survey respondents claimed they were unsure what percentage of project participants return each year to participate again. Low retention rates may indicate that CS project participants were unhappy, unsatisfied, and/or unenriched by their data-collecting experience, while high retention rates could indicate the opposite. Not knowing whether or not your participants return for another season of data collection demonstrates poor investment in project success.

When asked what criticisms and praises CS projects have received from project participants, many respondents (37%) claimed that they have not received any complaints from program participants, but most provided at least one example of complaints they receive. Among these complaints, most fell into one of three categories: procedure confusion, procedure difficulty, or technical problems. One example comes from a project based in Fort Collins, Colorado. The survey respondent asserts one of their biggest complaints is “not keeping up adequately with technology – many volunteers want [smart phone] apps and we haven’t been able to keep up”. Although this was classified as a technical problem, it sounds similar to complaints of waning interest. If CS project participants become fed up with the obsolete technology used in data collection, their interest in the project will probably wane, thus leading them to cease participation. Less common complaints included administrative problems, such as project coordinators not responding to participant emails in a timely fashion, or participants not feeling valued enough. Since technical problems, such as website glitches, tended to be the most common complaint, this is an area CS project coordinators should work on improving. A little investment in ensuring a well-functioning set of tools for participants could yield higher participant satisfaction and overall higher project success.

Positive feedback is often underrated in an evaluation process. Many project coordinators feel that 'praise' is nice to hear, but is not as helpful as constructive criticism. However, positive feedback can be useful in a number of ways.[95] One value of positive feedback is that it serves as evidentiary support for future grant-funding. Potential funders are likely to support a CS project that gathers important data as well as provides meaningful experiences to participants. Praise from participants also serves as valuable marketing to recruit future participants. If a parent had a great experience collecting data with his or her children, another parent who reads about their wonderful experience may be likely to give the CS project a try. Finally, positive feedback can be used to redesign CS projects. CS project coordinators may choose to emphasize certain components of their projects that received positive participant feedback and deemphasize other components which were difficult, confusing, or unsuccessful. Without positive feedback, CS project coordinators would have a hard time fairly assessing their projects. Survey respondents were asked to provide examples of praise they have received from participants over the years. Among these freeform responses, some patterns emerged. While only a few respondents claimed they have not received any praise on their projects, most claimed that they did have received praise. These types of praise fell into six

[95] "Benefits of Evaluation". Retrieved July 15, 2013, from https://www.bja.gov/evaluation/guide/documents/benefits_of_evaluation.htm

different categories.  The most common form of praise indicated by respondents was the educational value of citizen science – that is, participants enjoyed learning about the organism or environment at hand.  Beyond learning, participants also praised administrative aspects of CS projects.  This includes praising the functionality of a CS project's website, the knowledge and helpful demeanor of the staff, or the design of the project.  An equal number of survey respondents claimed praise that falls into the category of 'recreation' – either participants claimed to have a lot of fun collecting data, or they specified that they enjoyed getting to spend time outside while participating in the project.  A smaller number of CS projects claim their participants praise them because they feel 'useful', or like they 'made a difference'.  Very few projects claimed their positive feedback came in the form of awards received.  Figure 9 shows the breakdown of praise received by the survey respondents.

An important observation about CS project feedback – both positive and negative – is that, in general, projects seem to receive much more positive feedback than negative feedback.  While 37% of survey respondents claim they have not received any complaints about their projects, only 8.5% of survey respondents claim they have not received any praise.  CS project coordinators can benefit from this knowledge by realizing that, overall, participant satisfaction is very high.  It seems that CS projects have invested a lot of time up to this point in ensuring user-friendly methods, educational value, and enjoyable procedures for their participants.  It is possible that CS project coordinators might over-report participant praise and under-report participant complaints, however.  It is also important to note that CS participation is somewhat of a self-fulfilling prophecy.  For the most part, citizens choose to participate in CS projects because they already are convinced that the experience will be fun, educational, or beneficial in some other way.[96] Only a small number of survey respondents indicated that their project participants got involved with their project only because a teacher or professor required it of them. Since participant satisfaction tends to be very high, perhaps it is time for CS project coordinators to now move on to other aspects of project improvement – such as any of the complaints referenced earlier (technical problems, confusing procedures, etc.).

*Project Goals*

In the existing body of literature on citizen science, very few publications address which CS projects include educational goals or objectives.[97] In order to understand educational outcomes, it is imperative to look at the goals and objectives of CS projects. In other words, a discrepancy between objectives and outcomes would suggest that there should be major reform in the strategic planning of the project.

In the results section, it was shown that 92% of CS projects claimed that they did have specific goals related to environmental education. Among these respondents, responses were evenly split between goals of environmental literacy and goals of environmental stewardship. However, many respondents (38%) admitted that these goals were not officially written down anywhere and therefore they could not provide excerpts. The lack of reference to environmental literacy and stewardship is surprising, considering that nearly 60% of these same respondents indentified increased knowledge and contribution towards stewardship as the main motivation for citizens to participate in CS

[96] Evans, C., Abrams, E., Reitsma, R., Roux, K., Salmonsen, L., & Marra, P. P. (2005). The Neighborhood Nestwatch Program: Participant Outcomes of a Citizen-Science Ecological Research Project. *Conservation Biology*, *19*(3), 589-594.
[97] Sachs, S., Super, P. E., & Prysby, M. (2008). Citizen Science: A Best Practices Manual and How it Can be Applied.

projects. Perhaps CS coordinators ought to incorporate more education and stewardship-specific objectives in their project goals if they want to increase participant recruitment. If 92% of CS projects have goals of environmental education and/or stewardship, then we would expect to see more examples of these goals in the projects' mission, vision, or objective statements. This discrepancy between perceived and actual goals indicates that many CS projects may have unofficial, unwritten, or secondary goals of education and/or stewardship, but these goals do not appear anywhere except in the minds of the people running the projects. This poses a problem – having objectives regarding achieving environmental literacy and stewardship holds CS projects accountable for their goals. If the education and stewardship objectives are intangible – that is, not recorded anywhere – and only perceived by the CS project coordinators, then the project objectives can easily change at the slightest turnover of staff or direction. CS projects need to be more precise about their goals – not only for the sake of those choosing to volunteer, but also for the sake of presenting a transparent mission statement to potential funders. Without clearly defined, written goals, CS projects can never hope to effectively evaluate their outcomes and achieve greater success.

While many CS project coordinators may use evaluation techniques in order to better the scientific progress of the project, others also use it to evaluate educational outcomes. How the evaluation techniques are used should be determined by the goals and objectives of the project. For example, if the project has a goal to increase scientific literacy about species invasions by involving volunteers in weedy plant removal, the evaluation should include a way to assess if scientific literacy has, in fact, increased by the end of the project's season. If the project's only goals are to collect as much wide-reaching data as possible, then the evaluation need not include an educational assessment. Since only 8% of project respondents claimed that their CS project does not have any educational goals, most CS projects should include some kind of educational-outcomes evaluation. Since 92% of survey respondents identified with at least one educational objective, but up to 40% of these same respondents do not have an evaluation program in place, this discrepancy indicates that many more CS project coordinators could be incorporating valuable assessments of educational outcomes – but perhaps lack the tools or motivation to do so.

*Demographic Data*

When survey respondents were asked about the ages of their project participants, the data reflected a very steady increase in demographics. Not surprisingly, almost all (all but three) projects targeted adults for their participant base. Citizen science projects have been criticized in the past for not engaging our youth as much as they could. Since it has been shown that involving adults in CS projects only engages citizens that are already interested in and knowledgeable of conservation efforts[63], perhaps it would benefit CS project coordinators to expand their participant base to younger citizens. By doing so, impressionable students could be greatly impacted by the project – increasing their environmental literacy, adjusting their environmental attitudes, and aligning with conservation advocacy. CS projects can also be helpful in teaching young students about the scientific method, especially in conjunction with school science standards. In other words, younger students may have more to gain educationally from volunteering for CS projects than adults.

## CHAPTER 3 – RECOMMENDATIONS & CONCLUSIONS

### Recommendations

*Taxonomic Gaps*

It was projected that many taxonomic groups would be underutilized in citizen science projects nationwide. It was thought that reptiles, amphibians, non-insect invertebrates, and microorganisms (such as bacteria) would be the least present in CS projects due to factors such as charismatic draw and ease of observation. Data gathered from CS project websites, as well as from a distributed survey confirmed that herpetological fauna and microorganisms were indeed underrepresented in the canon of citizen science – both historically and currently. An additional finding was that projects involving fish and fungi are also limited. It is recommended that scientists who study these taxonomic groups ought to consider avenues of research that include citizen science. Citizen science projects are inclusive of the general public, and exposure to limited taxonomic groups leaves the public with the impression that certain taxa are not worthy of our time, study, or funding. Perhaps it is difficult for scientists who study reptiles or fungi to develop CS projects because there are so few model projects to use as a template for reptilian of mycological CS research. However, it should be noted that important lessons can be learned from any long-standing citizen science project – regardless of the taxa studied. Projects like the Christmas Bird Count which have been around for a long time, have valuable information to offer and a peek at their strategic planning, data collection protocols, and evaluation programming can serve as a useful template for setting up a new CS project, regardless of the taxa studied.

More studies should be done on evaluating the advantages and disadvantages of working with certain taxa. Many conservation ecologists choose to work with a particular species because they serve as indicators of ecosystem health. While many organisms are tolerant of changes to their habitats and adapt accordingly, several organisms are sensitive to the subtlest of changes. Conservation scientists use the presence or absence of these indicator species to assess the impact of human activities on ecosystems.[98] A well-known example of these 'bioindicators' are frogs. Amphibians, such as frogs, are sensitive to toxins in their aquatic environments primarily because of their permeable skin, and their "use of both aquatic and terrestrial habitats makes them vulnerable to environmental change".[99] Therefore, studies that use frogs as bio-indicators are usually concerned with air or water pollution – one of the most pressing issues concerning conservation scientists today. The use of bio-indicators in conservation research illustrates why it is important for scientists to thoughtfully and carefully choose the organisms with which they work. Species cannot simply be chosen at random for citizen science projects – they must correspond to areas of scientific inquiry. However, this example of frogs as bio-indicators brings an interesting point to light: If amphibians are such useful organisms for studying ecosystem health and conservation threats, than why are there so few citizen science projects that involve these taxa? Using bio-indicators in citizen science projects is a ripe opportunity, full of potential.

[98] Holt, E. A. & Miller, S. W. (2011) Bioindicators: Using Organisms to Measure Environmental Impacts. *Nature Education Knowledge* 3(10):8
[99] Sewell, D., & Griffiths, R. A. (2009). Can a Single Amphibian Species Be a Good Biodiversity Indicator?. *Diversity*, *1*(2), 102-117.

There are, of course, other reasons why some taxa remain so widely used in CS projects, while others are neglected. There are a myriad of natural history traits that could make one organism particularly difficult to work with – such as breeding behavior, being nocturnal, or defensive traits. There are also public perceptions of taxa which may influence potential volunteers' decisions to work on a particular CS project. Finally, concerns of liability and volunteer safety may be a reason why some taxa are chosen over others in the development of CS projects. A comprehensive study on taxonomic choices in CS projects would greatly benefit the citizen science community, and hopefully result in making the field of citizen science more well-rounded.

*Topic Gaps*

It was discovered that the vast majority of citizen science projects that exist today, exist for the purpose of revealing more about the natural history of a particular organism. That is, most projects are interested in gathering more basic data about an organism that is not very well understood – such as endangered species or an invasive species. This data often reflects information on the species' geographic range, migration patterns, or behavior in the wild. While there is nothing wrong with a CS project having a primary goal of acquiring new information about an organism, many CS projects opt instead to pose more detailed research questions about a variety of conservation ecology topics. Since biodiversity if considered by most conservation ecologists to be a measure of ecosystem health, the foundation of many CS projects is an assessment of biodiversity. It was discovered that most conservation ecology topics seemed to be distributed fairly evenly across the spectrum of CS projects, with one exception. This exception was the lack of projects focused on the topic of disease ecology. Since this is often identified as one of the most pressing topics in the field of conservation ecology, it is recommended that researchers in the field of disease ecology bolster the representation of this 'hot topic' in citizen science initiatives. Disease ecologists can collaborate with conservation ecologists in other fields – population ecologists, phenologists, and even natural resource managers – to learn the best ways to develop CS projects for their sub-discipline. If the goal of citizen science is at least partially to educate the public about pressing conservation issues, than it is the duty of CS project coordinators to ensure that the public is not mislead about what these pressing issues are.

While it is important to gather new information about any given species, some would argue that is more important to utilize citizen science in a way that does more than just reveal the natural history of said species. Rather, we should be using our CS projects to go one step further – to inform decisions regarding the protection of organisms and ecosystems. This is the difference between research in the field of ecology and research in the field of conservation ecology – the former wants answers to scientific inquiries, while the latter uses these answers to affect change. It is in this way that citizen science can be a very powerful tool, if aligned with the goals of conservation ecology. Further, by aligning more CS projects with conservation-oriented research, a sense of environmental stewardship will become inherent to all such projects. CS project participants will benefit from gaining scientific and environmental literacy, as is already the case with most CS projects – but in addition, participants will be challenged to act as representatives for conservation initiatives.

*Best Practices*

In addition to addressing the 'gaps' in citizen science, it is necessary to also address other trends in the field in order develop 'best practices' for CS project coordinators to strive towards. There are many obstacles along the road to developing and improving a discipline that is both young and interdisciplinary, but this is a necessary step in making any new field respected by colleagues, participants, and opponents. The process of creating a 'best practices' will help standardize the way CS projects are created and operated – which will set the bar for CS project directors the same way it has set the bar for nonprofit organizations. Many nonprofits find that "having a benchmark against which to measure their own practices is helpful" in holding themselves accountable to their goals.[100]

One recommendation for the creation of a 'best practices' is to formally and officially develop one organization, network, or research consortium which unites citizen science project directors globally. The United Kingdom has started to model this idea, as they have created both the UK Environmental Observation Framework, as well as the Citizen Science Alliance.[101] These organizations are valuable, but limited in their capacities. The Citizen Science Alliance, formed around 2007, is a "collaboration of scientists, software developers and educators who collectively develop, manage and utilize internet-based citizen science projects in order to further science itself, and the public understanding of both science and of the scientific process."[102] Although this is a

[100] "Principles and Practices". Retrieved June 30, 2013, from http://www.councilofnonprofits.org/resources/principles-and-practices
[101] UK Environmental Observation Network. Retrieved July 1, 2013, from http://www.ukeof.org.uk/co_citizen.aspx
[102] The Citizen Science Alliance. Retrieved July 1, 2013, from http://www.citizensciencealliance.org/index.html

valiant attempt to band together CS project stakeholders, it is limited to those projects which are internet-based. There are many CS projects currently running that employ different methods of data entry and observation recording. Additionally, most of the programs partnered together in the Citizen Science Alliance are meteorological or astronomical in nature. Perhaps it would be worthwhile to have a separate branch of the Citizen Science Alliance that focused on projects in conservation ecology. A bigger umbrella organization for citizen science projects is needed – one that will allow collaboration between scientists and social scientists, one that will host conferences and workshops for CS stakeholders, and one that will encourage the sharing of important findings in citizen science research. Only then will CS stakeholders be able to agree on a set of 'best practices'. The creation of a CS network or research consortium could also increase publishing, partnership, and conference opportunities, which would all contribute to advancing the discipline of citizen science and enlightening those researchers invested in it.

The UK Environmental Observation Network took an important step in the formation of a system of 'best practices' by creating their 'Guide to Citizen Science' in 2012. However, this guide was written and funded by only British stakeholders. In the future, citizen science project coordinators from all over the world should collaborate on an updated guide. Until then, the existing guides to citizen science practices will be limited by regional bias and perspective.

'Best practices' in citizen science should include the exploration of various evaluation methods. In the context of surveying CS project coordinators, it was revealed that many projects do not include any kind of evaluation programming, because of lack of knowledge on how to implement evaluation or lack of understanding that such programming is necessary for the continued improvement of citizen science. Evaluation is not common in inquiry-based scientific studies but is institutionalized in fields like nonprofit management, sociology, and education. CS stakeholders with experience and understanding of evaluation programs need to come forward to offer their skills, and scientists lacking these skills must recruit help from their colleagues in other fields.

Another component of citizen science ‘best practices’ should be the formal inclusion of educational goals in projects that are conservation-oriented. Educational objectives, such as increased scientific literacy, improved environmental attitudes, and increased environmental stewardship, need to be written alongside the scientific objectives and publicized. Doing so will hold CS project coordinators accountable for achieving their goals and potentially recruit more volunteers.

Of the many citizen science projects based in the United States, about 50% are geographically limited to a particular region of the country. There is no evidence to suggest that a smaller CS project is more effective at collecting data than a more large-scale, nationwide project. There is, however, reason to believe that there are some advantages to starting small and expanding. Many projects surveyed indicated that they originally had no intentions of expanding beyond their initial region, but over time the change became necessary due to public interest or funding opportunities that arose. Perhaps another ‘best practice’ could entail CS projects starting out as a small, regional pilot study in order to allow time for evaluation, regrouping, and expansion. Starting out small and expanding if necessary seems more desirable than investing a lot of resources into a large-scale project and having to downsize if the project does not go as planned.

Stakeholders in citizen science should be aware of the possibility of the 'duplication of services' that might arise with the explosion of CS projects in the last twenty years. There are now so many CS projects just in the United States that an overlap in project goals is starting to exist. For example, there are three projects in the United States that study bees, with regards to colony collapse disorder. They are Bee Hunt, Bee Spotter, and The Bumble Bee Conservation Initiative.[103] [104] [105] While these projects are asking slightly different research questions and are based in different parts of the country, they are still very similar in nature. Having multiple CS projects with similar research agendas may put those individual projects at a disadvantage because they could be competing for volunteers. These projects would benefit by banding together to form a network or partnership because this would ultimately yield are much larger dataset and increased publication opportunities.

## Conclusions

Previous literature has suggested that students as young as 3rd grade can be quite receptive to learning data collecting techniques, and beyond that, fairly adept at it. Despite this knowledge, most CS projects are still not targeted to younger students because of the perceived limitations. There are some obvious advantages to working with school groups: 1) mobilizing a large, captive audience with extrinsic motivators to succeed, and 2) participants that are more receptive to CS projects' educational goals. When adults participate in CS projects, the do so, in large part, because they already have

[103] Discover Life: Bee Hunt. Retrieved June 28, 2013, from http://www.discoverlife.org/bee
[104] Beespotter!. Retrieved June 28, 2013, from http://beespotter.mste.illinois.edu
[105] Project Bumble Bee. Retrieved June 28, 2013, from http://www.xerces.org/bumblebees/#nestwatch

environmental interests and are already somewhat environmentally literate. Therefore, the amount of scientific or environmental literacy they gain may be minimal. When a student participates in a CS project as a requirement for a class, they stand more to gain from participation. Younger students especially are a ‘clean slate’, presumably lacking more knowledge of the subject area than an adult. More research needs to be done – especially by educators and psychologists – to illuminate how early childhood psychology plays a role in developing environmental attitudes and stewardship as a response to participation in citizen science.

Citizen science has been an exciting development at the interface of scientific inquiry and education since the dawn of the $20^{th}$ century. Relatively recent advances in technology have allowed the field of citizen science to make great strides in a short period of time. While citizen science is a powerful tool for many branches of science, it is uniquely suited for conservation ecology. Citizen science projects take advantage of humankind’s “biophilia” and promote environmental stewardship – and in doing so, promote the goal of conservation itself. Citizen science is mutually beneficial to volunteer participants and conservation scientists, although it provides different benefits to each, and is perhaps the most efficient way for conservation ecologists to acquire broad-scale data for long-term research projects. In order for citizen science to reach its full potential, CS coordinators must strive to close the gaps of neglected taxonomic groups and important conservation topics. Once this challenge has been accepted, and CS stakeholders from overlapping disciplines unite to form a ‘best practices’ system, citizen science may truly be the most powerful tool for conservation in the 21st century and beyond.

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APPENDICES

## *Appendix A – Citizen Science Project Database*

| **Key** | |
|---|---|
| Biodiversity | BD |
| Resource Management | RM |
| Population Dynamics | PD |
| Phenology | P |
| Global Climate Change | GCC |
| Disease Ecology | DE |
| Water/Air Quality | WAQ |
| Natural History | NH |
| Invasive Species | IS |
| Other | O |

| Organization | Location | Founded | Host | Topic | Species |
|---|---|---|---|---|---|
| Acoustic Bat Monitoring | Fall Creek, WI | ? | partnership | PD | Mammals |
| Adirondack All-Taxa Biodiversity Inventory | Paul Smiths, NY | 2005 | university | BD, NH | All biota |
| American Kestrel Parnership | Boise, ID | ? | partnership | PD | Birds |
| Annual Midwest Crane Count | Baraboo, WI | 1976 | nonprofit | PD | Birds |
| AntWeb | San Francisco, CA | 2002 | nonprofit | BD | Invertebrates |
| Audubon Christmas Bird Count | Springfield, MA | 1900 | nonprofit | PD | Birds |
| Barcoding Life's Matrix | Ventura, CA | ? | partnership | BD, O | All |
| Bark Beetles and Rainfall | Phoenix, AZ | ? | partnership | GCC, PD | Invertebrates |
| Bay Area Bio Atlas | San Francisco, CA | ? | nonprofit | GCC, BD | All |
| Beach Watch | San Francisco, CA | 1993 | nonprofit | BD, RM, PD, P, GCC, DE, NH, IS | Abiota, mammals, birds, inverts |
| Bee Hunt | Athens, GA | ? | university | GCC, PD | Invertebrates |
| Bee Spotter | Urbana-Champaign, IL | ? | university | PD | Invertebrates |
| Bird Sleuth | Ithica, NY | 2004 | university | BD | Birds |
| Birds in Forested Landscapes | Ithica, NY | 1993 | university | PD, RM | Birds |
| Bucket Brigade | El Cerrito, CA | 2001 | partnership | WAQ | Abiota |
| Bumble Bee Conservation Initiative | Portland, OR | ? | nonprofit | DE, PD | Invertebrates |
| Butterflies and Moths of North America | Fort Collins, CO | 1995 | nonprofit | O | Invertebrates |
| Calflora | Berkeley, CA | ? | nonprofit | BD | Plants |
| California King Tides Initiative | San Francisco, CA | 2010 | partnership | GCC | Abiota |
| California Nature Mapping | Fresno, CA | 1992 | university | BD, O | All |
| California Roadkill Observation Program | Davis, CA | ? | university | PD | Animals |
| Caretta Research Project | Savannah, GA | 1973 | nonprofit | NH | Abiota, herps |
| Celebrate Urban Birds | Ithica, NY | ? | university | PD, O | Birds |
| Citizen Monitoring of Wisconsin's Freshwater Sponges | Milwaukee, WI | 2007 | partnership | PD, IS, BD, P, WAQ | Invertebrates |

| | | | | | |
|---|---|---|---|---|---|
| Citizen Sky | Denver, CO | 2009 | partnership | O | Abiota |
| Citizen Weather Observer Program | Cudjoe Key, FL | ? | federal gov't | O | Abiota |
| CitSci.org | Fort Collins, CO | 2005 | partnership | O | All |
| Clean Boats, Clean Waters | Fall Creek, WI | ? | DNR | IS | Plants |
| COASST | Seattle, WA | 1998 | partnership | RM | Abiota |
| Coastal Breeding Bird Monitoring | Quincy, MA | 2007 | NPS | PD | Birds |
| CoCoRaHS | Fort Collins, CO | 1998 | university | GCC | Abiota |
| Common Sense | Oakland, CA | 2009 | nonprofit | DE, WAQ, O | Abiota |
| Cricket Crawl | New York, NY | 2009 | partnership | PD, BD | Insects |
| Discover Life - Mothing Project | Athens, GA | 2010 | university | PD, WAQ, GCC, P, NH, BD, IS | Insects |
| Dragonfly Swarm Project | Tuscon, AZ | ? | private org. | O | Invertebrates |
| eBird | Ithica, NY | 2002 | partnership | IS, PD, GCC, RM, WAQ, BD, P, NH | Birds |
| Encyclopedia of Life | Washington, D.C | 2007 | partnership | BD, O | All |
| Firefly Watch | Boston, MA | 2008 | nonprofit | P, NH | Insects |
| Florida Butterfly Monitoring Network | Gainesville, FL | 2003 | partnership | PD, RM, BD, P, GCC, NH | Insects |
| Forest Breeding Bird Monitoring | Acadia, ME | 2006 | NPS | PD, RM | Birds |
| Forest Salamander Monitoring | Woodstock, VT | 2006 | NPS | PD, RM | Amphibians |
| Fresno Bird Count | Fresno, CA | ? | university | PD, O | Birds |
| FrogWatch | St. Louis, MO | 1998 | partnership | PD, DE | Amphibians |
| Fungi Mapping | Tremont, TN | ? | partnership | PD | Fungi |
| Galloway Creek Water Quality Monitoring | Menomonie, WI | 2003 | partnership | WAQ | Abiota |
| Global Amphibian Blitz | Stanford, CA | ? | partnership | PD | Amphibians |
| Global Garlic Mustard Field Survey | Durham, NC | ? | federal gov't | IS | Plants |
| GLOBE at Night | Tuscon, AZ | 2006 | partnership | O | Abiota |
| Great Backyard Bird Count | Ithica, NY | ? | partnership | PD | Birds |
| Great Lakes Worm Watch | Duluth, MN | ? | university | IS | Invertebrates |
| Great Sunflower Project | San Francisco, CA | 2008 | partnership | PD, O | Plants |
| Great World Wide Star Count | Boulder, CO | 2007 | university | O | Abiota |
| Grunion Greeters | Malibu, CA | ? | partnership | PD, RM | Fish |
| Hawk Watch | Acadia, ME | 2005 | nonprofit | PD | Birds |
| Hoosier Riverwatch | Indianapolis, IN | 1996 | DNR | WAQ | Abiota, insects |
| House Finch Disease Survey | Ithica, NY | 1994 | university | PD, DE | Birds |
| Hudson River Eel Project | Poughkeepsie, NY | 2008 | regional gov't | PD, GCC, RM, P, NH, WAQ | Abiota, fish |
| IceWatch USA | Clearfield, PA | 2008 | nonprofit | GCC, PD | Abiota, mammals, birds, herps |
| Illinois RiverWatch Network | Godfrey, IL | 1995 | partnership | RM, BD, WAQ | Abiota, insects, other inverts |
| Intertidal Investigations | Acadia, ME | 2013 | NPS | IS, WAQ, PD, GCC, RM, BD, P | plants, other inverts |
| Invaders of Texas | Austin, TX | 2005 | partnership | IS | Plants |
| Invasive Tracers | Quincy, MA | 2007 | partnership | IS | plants, other inverts |
| Jay Watch | Lakeland, FL | 2002 | nonprofit | PD | Birds |

| | | | | | |
|---|---|---|---|---|---|
| JellyWatch | Monterray, CA | 2010 | nonprofit | IS, BD, NH | Invertebrates |
| Journey North | Norwich, VT | 1997 | partnership | NH | All |
| Jug Bay Volunteer Program | Lothian, MD | ? | partnership | NH, PD | Abiota/Invertebrates/Plants |
| Juniper Pollen Project | Tuscon, AZ | ? | partnership | O | Plants |
| Killer Whale Tracker | Olympia, WA | ? | partnership | PD | Mammals |
| Let There Be Night | Mishawaka, IN | 2009 | partnership | O | Abiota |
| Lichen Monitoring | Tremont, TN | 1998 | partnership | BD, WAQ | Plants |
| LiMPETS | Santa Cruz, CA | 2002 | partnership | RM | All |
| Long-Billed Curlew Survey | Los Angeles, CA | ? | nonprofit | NH | Birds |
| Lost Ladybug Project | Ithica, NY | 2000 | university | PD | Invertebrates |
| Maine Volunteer Lake Monitors | Auburn, ME | 1971 | nonprofit | WAQ | Abiota |
| Makai Watch | Honolulu, HI | ? | partnership | GCC, IS, 0 | Invertebrates/Plants |
| Minnesota Frog & Toad Calling Survey | St. Paul, MN | 1996 | DNR | PD, NH | Amphibians |
| Minnesota Loon Monitoring Program | Bemidji, MN | 1994 | DNR | PD, NH | Birds |
| Minnesota Odonata Survey Project | Finland, MN | ? | regional gov't | PD, NH | Invertebrates |
| Monarch Larvae Monitoring Project | St. Paul, MN | 1996 | university | PD, BD, DE, P, NH | Abiota, insects |
| Monarch Watch | Lawrence, KS | 1992 | university | NH | Invertebrates |
| Mountain Birdwatch | Norwich, VT | 2000 | partnership | PD, NH | Birds |
| Mountain Watch | Boston, MA | 2003 | nonprofit | P | Plants/Abiota |
| Native Buzz | Gainesville, FL | 2011 | university | NH, P, BD, RM, GCC, PD, IS, DE | Abiota, insects |
| Nature's Notebook | Tuscon, AZ | ? | partnership | P | All |
| Nest Watch | Ithica, NY | 1997 | university | NH | Birds |
| NJ Shorebird Survey | Cape May, NJ | 2010 | partnership | NH | Birds |
| NJ Watershed Watch Network | Trenton, NJ | ? | regional gov't | WAQ | Abiota |
| North American Amphibian Monitoring Program | Patuxent, MD | 2004 | federal gov't | PD | Amphibians |
| North American Bird Phenology Program | Laurel, MD | 2009 | federal gov't | IS, NH, GCC, P | Birds |
| North American Breeding Bird Survey | Laurel, MD | 1966 | federal gov't | PD | Birds |
| NY Horseshoe Crab Monitoring Network | Riverhead, NY | ? | partnership | PD | Invertebrates |
| OakMapper | Berkeley, CA | 2001 | partnership | PD, DE | Plants/pathogens |
| Ohop Wildlife Monitoring Project | Eatonville, WA | 2009 | partnership | NH | Birds, mammals, amphibians |
| Operation RubyThroat | York, SC | 1996 | nonprofit | RM, BD, P, NH, GCC, PD | Birds, plants |
| OPIHI | Manoa, HI | ? | partnership | NH, IS | Abiota/Invertebrates |
| Otter Spotters | San Francisco, CA | ? | partnership | NH | Mammals |
| Ozone Garden | Tremont, TN | ? | partnership | GCC, WAQ | Plants |
| Pacific Flyway Shorebird Survey | San Francisco, CA | 1988 | nonprofit | NH | Birds |
| Phenology Monitoring | Tremont, TN | ? | partnership | GCC, PD | All |
| Philly TreeMap | Philadelphia, PA | ? | partnership | O | Plants |
| Pigeon Watch | Ithica, NY | ? | university | PD, O | Birds |
| Plants of Concern | Chicago, IL | 2001 | partnership | PD | Plants |

| | | | | | |
|---|---|---|---|---|---|
| Prairie Phenology | Manhattan, KS | ? | university | P | All |
| Prairies Across Kansas | Manhattan, KS | ? | university | BD, NH | Plants/Invertebrates |
| Project BudBurst | Boulder, CO | 2007 | partnership | GCC, P | Plants |
| Project Butterfly WINGS | Gainesville, FL | ? | partnership | BD, NH | Invertebrates |
| Project FeederWatch | Ithica, NY | 1986 | university | PD, NH | Birds |
| Project MonarchHealth | Athens, GA | 2006 | university | DE | Invertebrates |
| Project NOAH | New York, NY | 2010 | university | P, NH, IS, PD, BD | All biota |
| Project Squirrel | Chicago, IL | 2006 | partnership | NH | Mammals |
| Puget Sound Seabird Survey | Puget Sound, WA | 2007 | nonprofit | PD | Birds |
| Rainlog | Tuscon, AZ | 2002 | university | RM, GCC, WAQ | Abiota |
| Raptor Population Index | Plymouth, NH | ? | partnership | PD, NH | Birds |
| Rare Plant Monitoring | San Francisco, CA | 2008 | partnership | BD | Plants |
| RasCals | Los Angeles, CA | 2010 | nonprofit | NH, O | reptiles, amphibians |
| REEF | Key Largo, FL | 1993 | nonprofit | PD, BD, IS | Abiota, fish, other inverts |
| Reef Check California | Pacific Palisades, CA | 1996 | nonprofit | BD, NH | Fish/Invertebrates/Plants |
| Roadkill Project | Boston, MA | 1992 | federal gov't | BD | Animals |
| Ruffed Grouse Drumming Survey | Albany, GA | 2009 | regional gov't | PD | Birds |
| Salt Marsh Monitoring Program | Cape Cod, MA | 2003 | nonprofit | WAQ, RM | Abiota |
| SC Oyster Restoration & Enhancement Program | Charleston, SC | 2001 | DNR | WAQ, RM | Invertebrates |
| School of Ants | Raleigh, NC | 2011 | university | PD, GCC, BD, NH, IS | Insects |
| S'COOL Rover | Hampton, VA | 2013 | federal gov't | GCC | Abiota |
| Sound Toxins | Seattle, WA | 2005 | partnership | DE, WAQ, PD, RM, BD | Abiota, plants, other inverts |
| Spider Survey | Los Angeles, CA | 1996 | nonprofit | NH, O | Invertebrates |
| Stardust@home | Berkeley, CA | 2006 | university | O | Abiota |
| Stream Team | Harding, NJ | 1980 | nonprofit | WAQ, RM, IS | Abiota |
| Summer Wild Turkey Sighting Survey | Albany, NY | 2009 | regional gov't | NH | Birds |
| Sword Ferns in the Redwood Ecosystem | Oakland, CA | ? | partnership | GCC, P | Plants |
| Terrestrial Salamander Monitoring | Tremont, TN | ? | partnership | BD, NH | Amphibians |
| The Bees Needs | Boulder, CO | ? | university | BD, PD | Insects |
| Tracking the Wild Invasives | New Brunswick, NJ | ? | partnership | IS | Plants |
| Turtle Roadway Mortality Study | Boston, MA | 2008 | regional gov't | RM | Reptiles |
| Upper Merrimack Monitoring Program | Concord, NH | ? | nonprofit | WAQ | Invertebrates/Abiota |
| Urban Ecology Center | Milwaukee, WI | 2000 | partnership | NH, DE, IS, WAQ, PD, GCC, BD, P | All biota |
| Utah Water Watch | Logan, UT | 2006 | partnership | WAQ | Abiota |
| Vanessa Migration Project | Ames, IA | ? | university | NH | Invertebrates |
| Vegetable Varieties for Gardners | Ithica, NY | 2004 | university | O | Plants |
| Virginia Master Naturalist Program | Blacksburg, VA | ? | partnership | PD, WAQ | All |
| Vital Signs | Portland, ME | 2009 | nonprofit | IS | Abiota, plants, fungi, herps, insects, other inverts |

| | | | | | |
|---|---|---|---|---|---|
| Watch the Wild | Clearfield, PA | 2008 | nonprofit | NH, P | All |
| Water Action Volunteers | Fall Creek, WI | ? | partnership | WAQ | Invertebrates, abiota |
| Weed Watchers | San Francisco, CA | ? | NPS | IS, NH | Plants |
| Whales & Glaciers Citizen Science Adventure | Juneau, AK | ? | private org. | GCC, WAQ | Mammals |
| Wild River State Park Prairie Care | St. Paul, MN | ? | DNR | IS, PD, RM, P, NH | Abiota, plants |
| WildLab | New York, NY | 2009 | nonprofit | NH, IS, PD, GCC, BD | Birds |
| Wildlife Health Event Reporter | Madison, WI | ? | nonprofit | NH | All animals |
| Wildlife Watch | Washington, D.C | ? | nonprofit | NH | All |
| YardMap | Ithica, NY | 2012 | university | IS, RM, BD | Abiota, plants, birds |
| ZomBee Watch | San Francisco, CA | ? | partnership | NH, DE | Invertebrates |

## *Appendix B – Citizen Science Survey Questions*

Page 1 of 1

# Citizen Science Survey

A survey of U.S. citizen science project managers.

**1** *
When was this project established?

Month | Day | 2013

**2** *
How many paid staff members does your citizen science project employ?

**3** *
Do you have any unpaid/volunteer staff who help with the coordination of your citizen science project? If so, how many?

**4a** *
Is the project still active? (i.e., is data collection still going on?)

- yes
- no
- data collection is done for the season, but will continue next season

**4b**
If the project is no longer active, when did the project permanently end?

Month | Day | 2013

**5** *
Where (city, state) is the project based? (i.e., where are the project coordinators located?)

**6a** *
Is your participant base restricted to a particular region?

- yes, it is restricted to a particular region of the united states
- no, anyone, nationwide, can participate

**6b**
If you answered 'yes' to 7a, describe the range from which your data is acquired (eg. only within the state of California, anywhere in the continental U.S., only within southeastern states, etc.).

**7a** *
Did the project initially start in a smaller location and then expand to include a larger area?

- yes, we started small and expanded
- no, we have always been in the same place
- actually, we started in a bigger location and have downsized to a smaller area since

**7b**
If you answered 'yes' to question 8a, was that the initial goal of the project? Or was expanding to include a larger participant base an unforeseen side-effect of project success?

- ○ yes, it was our goal all along to start small and expand later
- ○ no, we had no idea we'd be expanding our participant base at the time we started the project

**8a** *
How many participants did you have in your first season of data collection?

**8b** *
How many participants did you have in your most recent season of data collection?

**9** *
What age range does your citizen science program target? (Check all that apply)

- ☐ Pre-k/kindergarten
- ☐ Elementary students (grades 1-5)
- ☐ Middle students (grades 6-8)
- ☐ High students (grades 9-12)
- ☐ College/grad students
- ☐ Adults/seniors

**10** *
What percentage of your participants return each year to participate again?

- ○ <5%
- ○ Up to 25%
- ○ Up to 50%
- ○ Up to 75%
- ○ Almost 100%
- ○ Unknown

**11a** *

Do you have a method of evaluating your citizen science program?

- yes
- no
- unsure

**11b**

If your answer to 13a was 'no', why not?

- We have no one on staff who knows how to implement an evaluation program
- The program director doesn't think it is necessary
- We have no time/resources to make an evaluation program happen.
- We don't know what that is - it never occurred to us to have one.

**12a** *

On a scale of 1 to 5, how would you rate the participant success of your citizen science project?

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| no or very few people learned | | | | | | nearly everyone who attends leaves with a greater environmental literacy |

**12b** *

On a scale of 1 to 5, how would you rate the scientific success of your citizen science program?

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| little to no helpful data acquired | | | | | | the amount of helpful data we acquired exceeded our expectations |

**13** *

Which of these states matches most closely with your project's educational philosophy?

- 1. The goal of our CS programming is to make citizens better environmental stewards
- 2. The goal of our CS programming is to make citizens more environmentally knowledgeable
- 3. The goal of our CS programming is to make citizens more caring towards and have better attitudes towards the environment
- 4. The goal of our CS programming is to make citizens invested in conservation initiatives
- 5. The goal of our CS programming is to make citizens more interested in environmental issues.
- Our citizen science project does not have an educational goal.

**14** *

How many different ways are there for citizens to participate in your citizen science project? Please briefly explain.

**15** *
Do your project's objectives have any reference to environmental learning, environmental stewardship, or environmental attitudes?

**16**
If your project does attempt some kind of program evaluation, what kind of evaluation method do you use?

- [ ] outcomes-based evaluation
- [ ] pre/post tests
- [ ] participant surveys
- [ ] interviews
- [ ] focus groups
- [ ] Other:

**17** *
What would you say is the number one reason people choose to participate in your citizen science program?

- ○ because they want to help/give back
- ○ because it sounds like fun
- ○ because they want to learn more about the species/habitat involved
- ○ because a teacher/professor is requiring their participation
- ○ Other:

**18** *
What is the number one thing your citizen science project is struggling with?

- ○ getting enough participants
- ○ getting enough diversity of participants (from a broad enough geographic range)
- ○ 3. Getting confusing or inaccurate data from participants
- ○ 4. Making our data collection protocol "fool proof" enough for citizens
- ○ 5. Compiling data in a consistent and efficient manner
- ○ 6. Organizing all the volunteers who want to help
- ○ Other:

**19** *
What kinds of complaints (if any) have you received from project participants?

**20** *
What kinds of praise (if any) have you received from project participants?

**21** *

What conservation ecology topic(s) does your citizen science project address? (check all that apply)

- ☐ disease ecology/parasitology
- ☐ invasive species
- ☐ water/air quality
- ☐ population dynamics
- ☐ global climate change
- ☐ resource management
- ☐ biodiversity
- ☐ phenology
- ☐ natural history data (migration patterns, geographic range, survivorship, behavior, etc.)
- ☐ Other: ______

**22a** *

Does your citizen science project collect data on biota, abiota, or both?

- ○ biota (plants, animals, fungi, etc.)
- ○ abiota (pH, temperature, soil chemistry, etc.)
- ○ both biota and abiota

**22b**

If your citizen science project collects data on biota, which organism is the focus? (check all that apply)

- ☐ plants
- ☐ fungi
- ☐ mammals
- ☐ birds
- ☐ fish
- ☐ herps (reptiles and/or amphibians)
- ☐ insects
- ☐ other invertebrates
- ☐ Other: ______

**22c**

If your project collects abiotic data, please describe what this data is below (examples include water pH, temperature, air qualilty, etc.).

**23**

Please use this space to comment on questions that were difficult for you to answer because of the nature of your citizen science project(s).

*Appendix C - Figures*

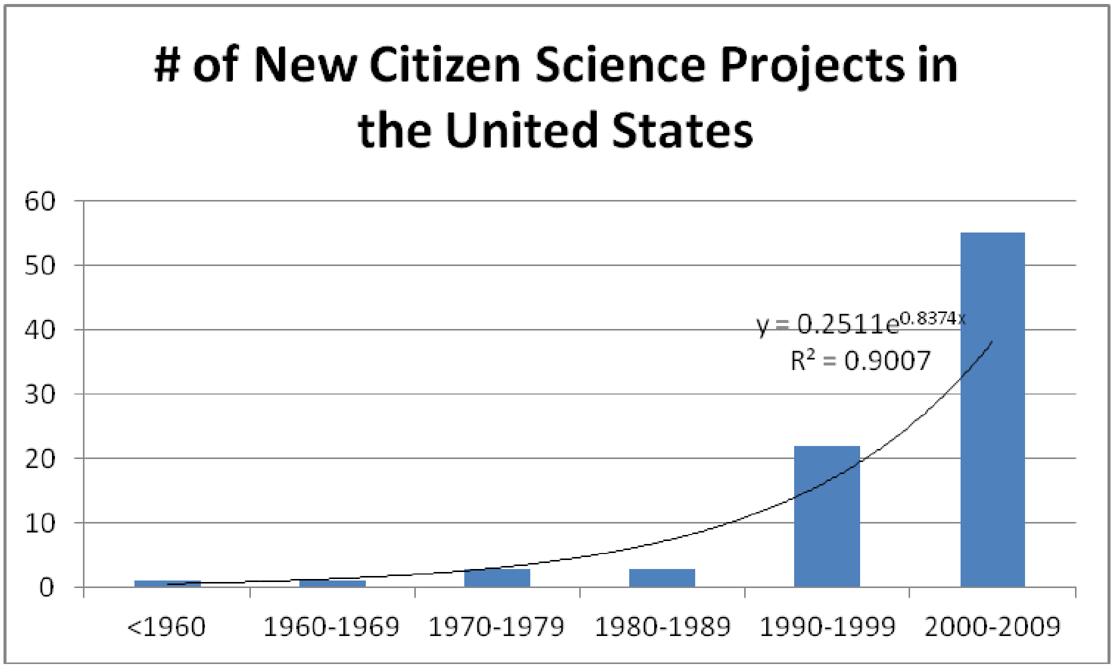


**Figure 1:** A graph showing the sudden increase in citizen science projects during the ‘Digital Revolution’

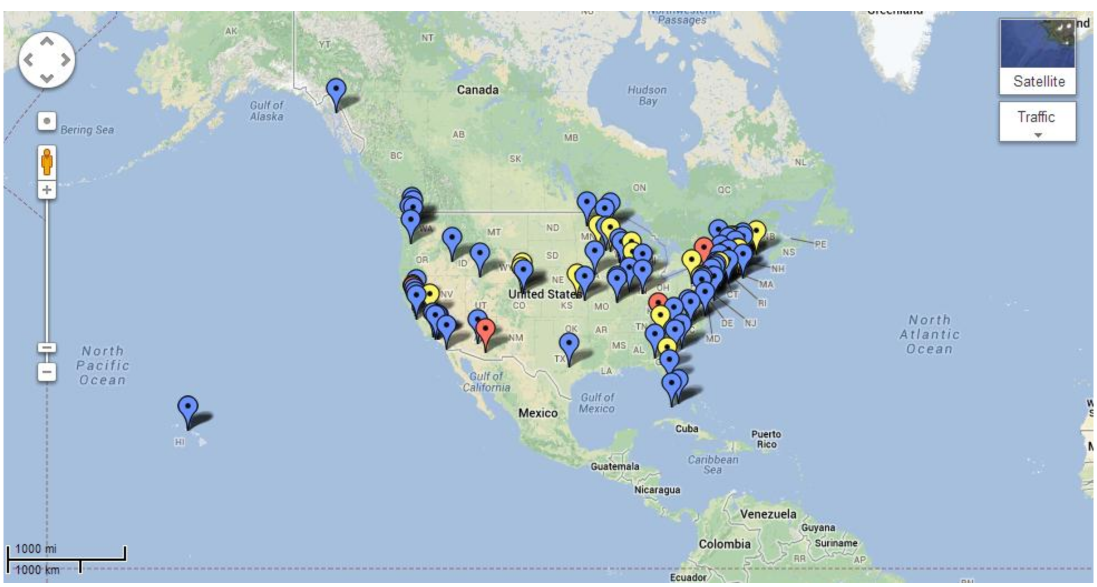


**Figure 2:** A map of citizen science projects in the United States; 95% are still running


**Figure 3:** An enlarged map of citizen science projects in the continental United States; red markers indicate citizen science 'hot spots'

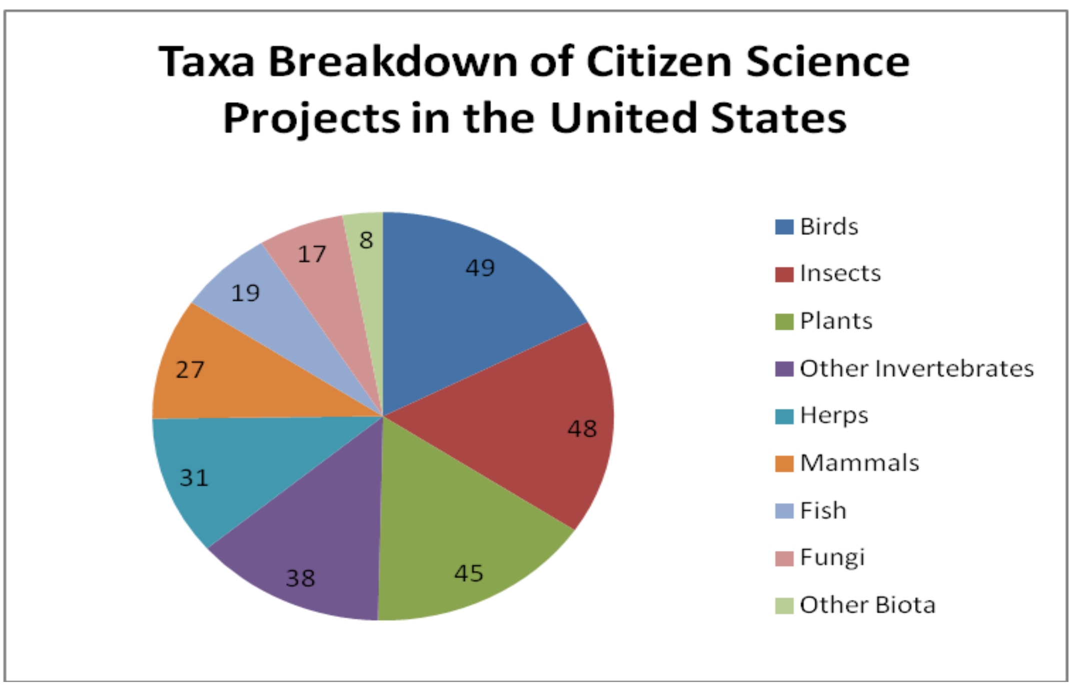


**Figure 4:** A pie chart showing the taxonomic breakdown of CS projects; only projects studying topics in conservation ecology are included

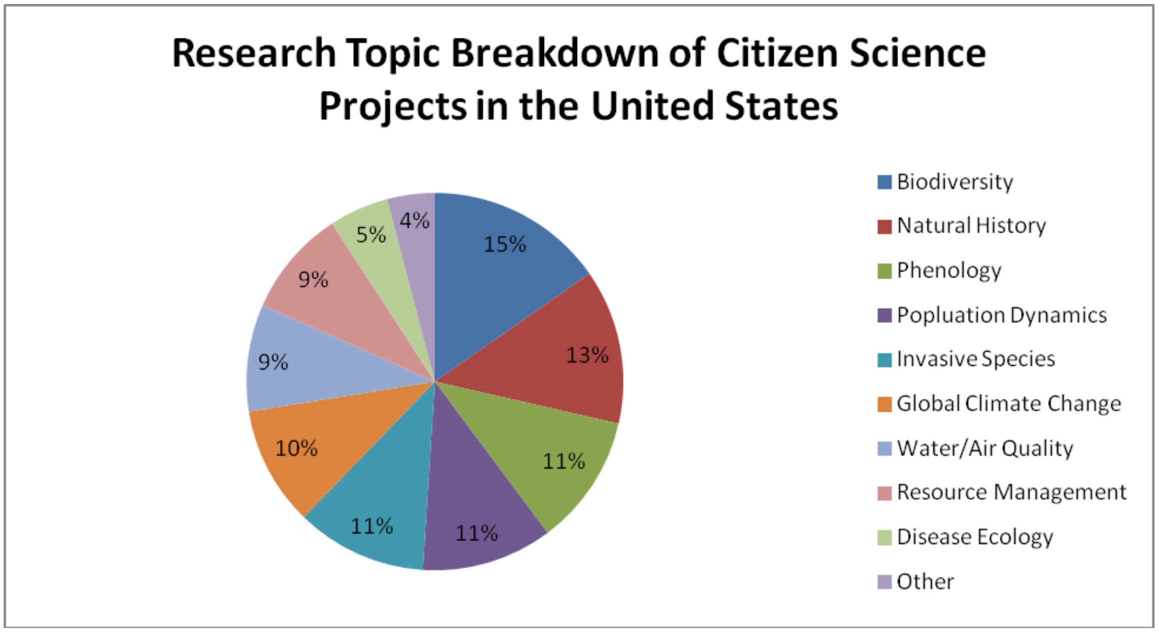


**Figure 5:** A pie chart showing the conservation topic breakdown of CS projects

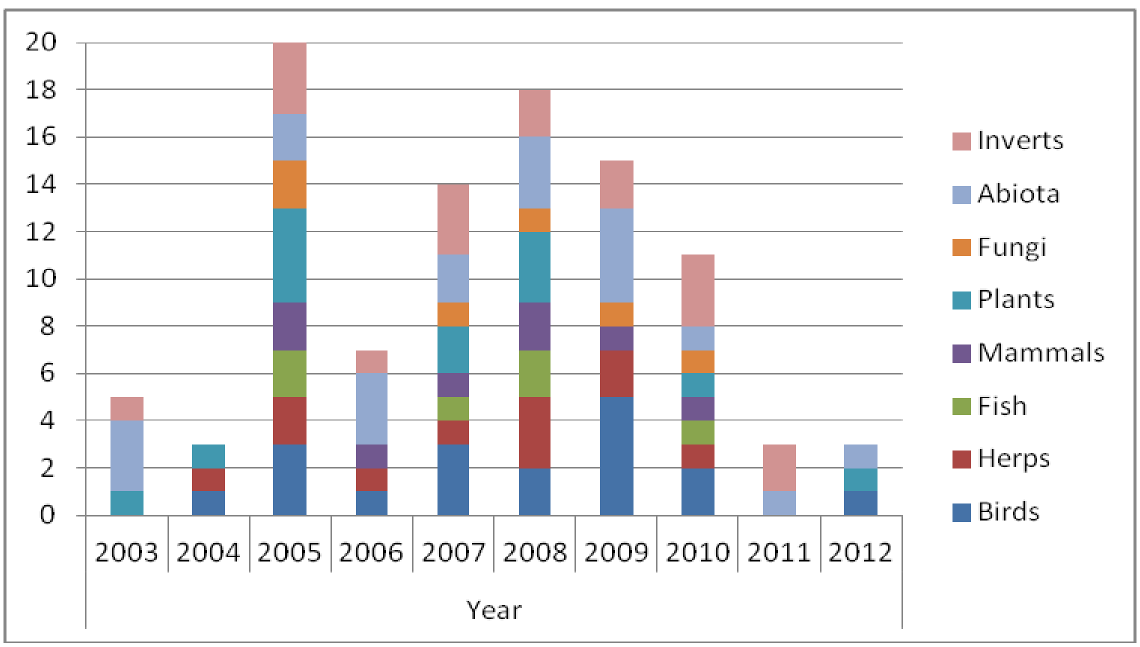


**Figure 6:** The taxonomic breakdown of recent CS projects

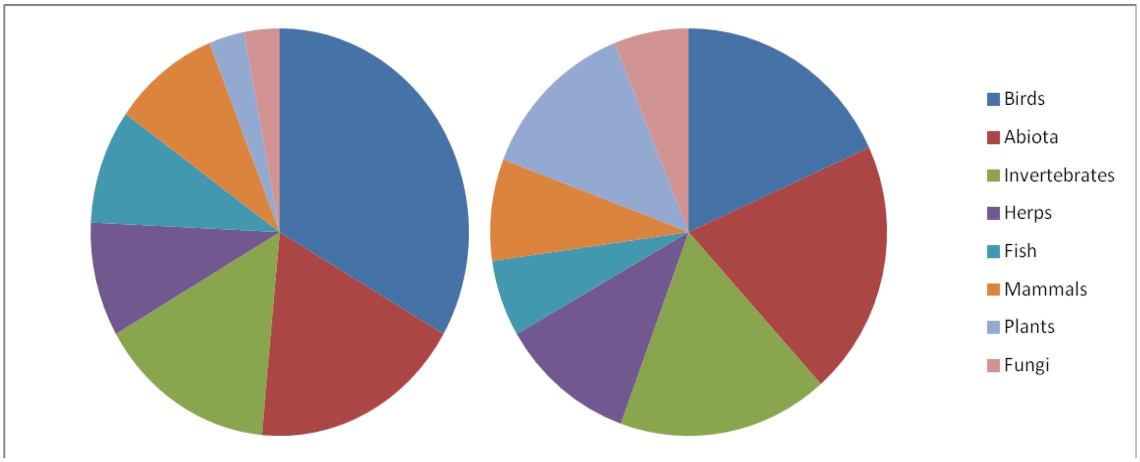


**Figure 7:** A comparison of taxonomic breakdowns for early CS projects (left) and recent CS projects (right)

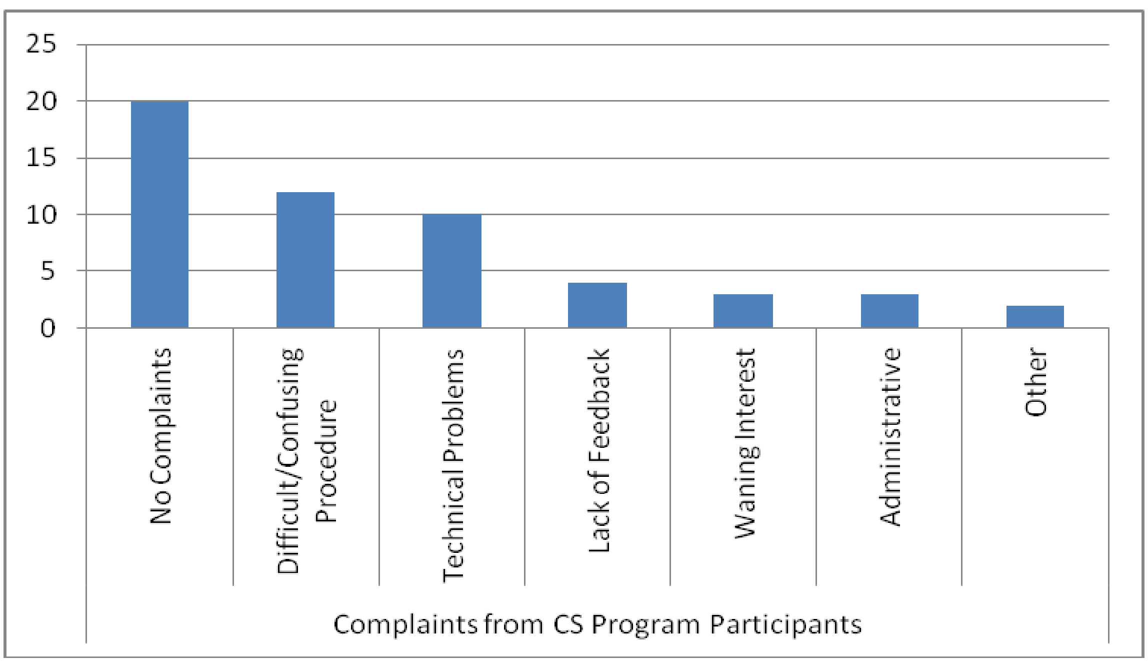


**Figure 8:** Categorization and distribution of complaints from CS project participants

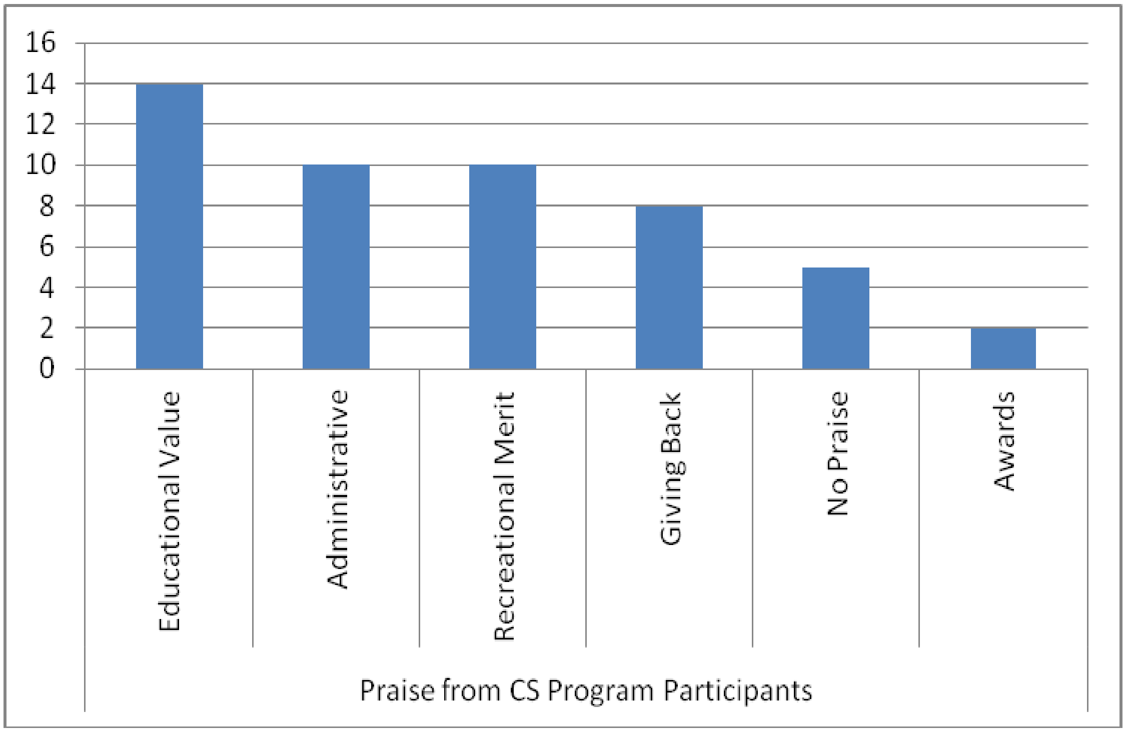


**Figure 9:** Categorization and distribution of praise from CS project participants

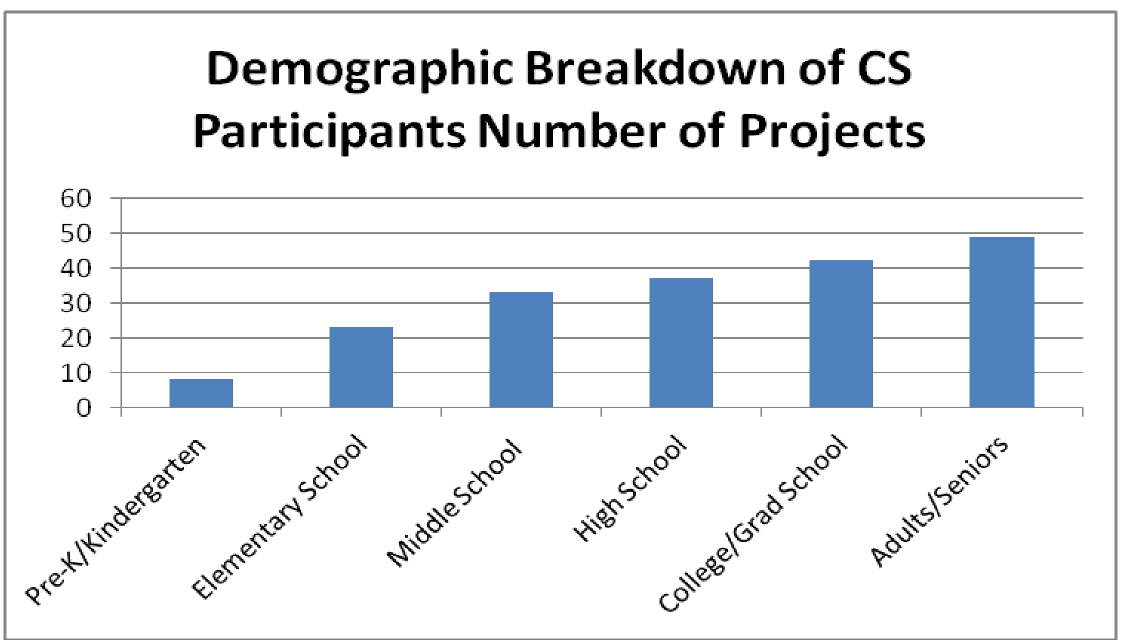


**Figure 10:** Chart showing how different age groupings are represented in CS projects